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THE EFFECT OF OVERLOAD WARM-UP ON VERTICAL JUMP AND SHOT-PUT PERFORMANCE

by

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A thesis

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The undersigned certify that they have read and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "The Effect of Overload Warm-Up on Vertical Jump and Shot-Put Performance" submitted by Ian Newhouse in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The primary purpose of this study was to explore the possibility of immediate temporary power gain, as seen in the vertical jump and shot-put performance through a warm-up of jumps and puts with added resistance.

Twenty-two skilled jumpers and 11 skilled shot-putters volunteered to participate in the study. The jumpers were top Edmonton area athletes active in track and field, volleyball or basketball, while the shot-putters' skill levels ranged from 9 to 14 meters for females and 12 to 16 meters for males. Half of the subjects were female, and all were between the ages of 18 and 31.

Each subject was tested under 3 different warm-up conditions for both the vertical jump and shot-put experiments:

1. Control "A", 1 pre-test trial/6 warm-up trials with no overload/ 1 post-test trial;
2. Control "B", 1 pre-test trial/no warm-up but a 7 minute rest/ 1 post-test trial;
3. Experimental, 1 pre-test trial/6 warm-up trials with overload, which was a 40 to 60 kilogram weight bar on the shoulders for the jumps and a 2 to 4 pound heavier shot for the puts/1 post-test trial.

The 6 possibilities of different test sequences were randomly assigned to the subjects.

In a supplementary experiment, 6 of the shot-putters warmed up with the heavier shot in an actual competition.

The jumping experiment made use of high speed photography, a force plate, and integrated electromyogram. In the shot-put experiment, the

only parameter measured was the distance of the put.

From 18 possible warm-up categories, statistical analysis found the post-test trial to be significantly better (at the 0.05 level) than the pre-test trial in the following 6 categories:

Sex	Group	Event
Male and female combined	Experimental	Vertical jump
Female	Experimental	Vertical jump
Male and female combined	Experimental	Shot-put
Male	Experimental	Shot-put
Male and female combined	Control "A"	Shot-put
Female	Control "A"	Shot-put

A second post-test trial was added for 6 of the subjects in the shot-put experiment, for it was felt that the timing of the movements might be offset by the overload warm-up. This brought a further significant improvement to the experimental group as the timing was apparently regained.

Although the experimental group did improve to a greater degree than either of the controls, a significant difference could not be found in comparisons between the three groups.

Despite the inconclusive findings, the results did show promise that the proper application of resistance in a warm-up could aid skilled performance in explosive power events.

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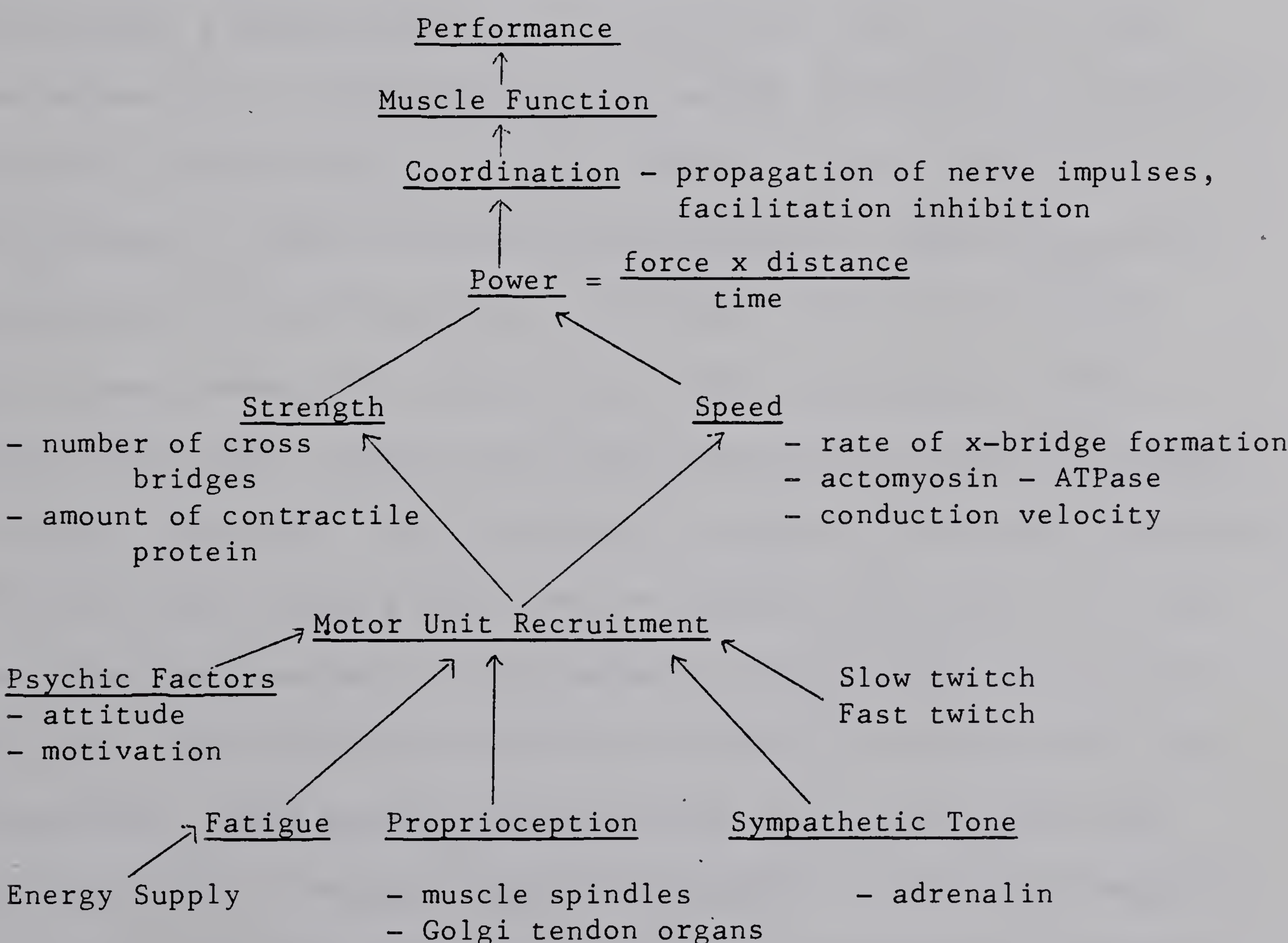
CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

The present study dealt with the parameter of explosive power, its contribution to performance, and the means by which an overload warm-up might increase power for ensuing competitive effort. Power is the time rate of doing work. It is a combination of strength and speed. When these two variables are directed towards a performance, coordination comes into play. An understanding of power becomes more complex when one considers the physiological basis behind it. The following performance model is an attempt to simplify the physiological components underlying power.

Figure 1: The Physiological Components Underlying Power



A number of athletic performances are power events. Short sprints, jumps, and throws all demonstrate maximum muscle contraction over a minimum of time.

A sensation of increased power is common in our daily lives when we suddenly reduce the resistance in a movement; for example, after removing heavy overshoes our legs feel much lighter, or, after changing gears on a bike, the pedals move more easily. Is the after-effect of performing with resistance purely psychological, or is there a physiological benefit as well? The idea of incorporating resistance exercises into a warm-up is not new to explosive power events. Baseball batters can often be seen preparing for their turn at bat by swinging three bats at once or by swinging a weighted bat. Their counterparts may warm up their pitching arm by throwing a weighted baseball. In the 1950's and '60's, a number of researchers (11,14,83,84,85,90,98,110) studied the benefits of overload warm-ups but with conflicting results. Perhaps the best testimonial of an overload warm-up is that of the world class athlete. "Does warm-up with a heavier shot help a shot-putter?" "It works, believe me it works," asserts Carmen Ionesco,(55) Canada's top female shot-putter. Diane Jones-Konihowski,(56) Canada's gold medal pentathlete at the 1978 Commonwealth Games, notes that some specificity in terms of timing and coordination could be lost after using a heavy shot for much of the warm-up. For this reason, Diane switches back to the regulation shot for the last couple of warm-up puts. Some athletes ignore the specificity of movement but still claim benefits. Geoff Capes of Great Britain, one of the world's best shot-putters, does a complete weightlifting workout just before competing; Canadian javelin thrower, Phil Olson, does handstand push-ups as part of his warm-up.(94).

The potential for immediate power increase is also supported by the unusual feats of strength that can be performed by people of ordinary muscular development when in hypnotic states, or when excited (18); an example of this may be the often-repeated story of a middle-aged woman lifting up a large car to free a child. These feats are often explained in a superficial way as due to strong motivation, determination, or a belief in self, but what is the physiological rationale? Long term physiological changes accompanying increased muscle power (i.e. muscle hyptertrophy and biochemical changes) (2.23) cannot explain a short term, temporary improvement. The control system for motor performance, the nervous system, could hold the key to understanding an immediate power increase. As Mathews and Fox (75) state in explaining extraordinary feats of muscular strength:

> Such feats could be explained on the basis that normally it is not possible, because of central nervous system inhibitions, to activate all of the motor units available within a muscle or muscle groups. Under extreme circumstances, such inhibitions would be removed and thus all motor units activated. A reduction in central nervous system inhibition with concomitant increases in strength and endurance would also seem to be a reasonable change that could be learned through weight training programs.

Can an overload warm-up also bring about a beneficial short term adaption of the nervous system? Van Huss (110) thought that this might be possible:

> In skilled movement it has been shown that motor unit activity follows a definite sequence. With additional load more motor units are activated and the rate of stimulation increased which should result in more muscle fibers being activated. With overload warm-up the additional motor units and/or fibers are brought into play and remain available when the extra load is removed.

This research studied an overload warm-up applied to the vertical jump and the standing shot-put. In the vertical jump experiment, high speed photography, a force plate, and integrated EMG were used. An electromyograph

helped test the hypothesis of increased motor activity as it can detect the electrical impulses leading to motor unit activation. An integrated EMG signal is linear to force as it takes into account the number of motor units recovered, their firing rate, and amplitude, therefore describing fully the electrical activity within muscles.(63) A force plate measured the force exerted while a filmed jump test simultaneously revealed how this related to performance. In the shot-put experiment, the distance of the put was the only parameter measured.

The review of literature will elaborate on the nervous system's role in explosive power output.

The Problem

To determine if performance in the vertical jump and shot-put can be enhanced by a warm-up with resistance overload.

Secondary Problem

To develop a physiological rationale to explain an immediate temporary improvement in performance if such an improvement could take place.

Delimitations

This study will be delimited to 22 skilled jumpers and 11 skilled shot-putters from the Edmonton area of approximate age 20 to 25. Only one method of applying resistance to the jumpts or puts was tested. It will take further study to determine the ideal amount and progression of resistance, the number of warm-up trials, and the amount of recovery between trials. The necessary procedures involved in a shot-put competition made control of recovery periods and number of warm-up puts difficult in the supplementary shot-put experiment. Performances in this supplementary experiment allowed

comparisons to the individual's personal best and recent shot-put performances. These comparisons were not valid, though, in the controlled shot-put experiment, for this was a standing shot-put without the added advantage of the glide. The focus of analysis in the study was on a performance criteria (i.e. height jumped or distance of put) as opposed to a technique criteria. Electromyograph analysis was used in just the jump test with the electrodes placed on the rectus femoris of the subject's left leg.

<u>Limitations</u> (for vertical jump experiment)

1. SUBJECT SELECTION. Although skilled jumpers were selected, not all of the subjects proved to be consistently good vertical jumpers.

2. USE OF FORCE PLATE. The oscilloscope measurement of the force plate tended to drift slowly downward if the subject stood on it for more than about 4 seconds. The subject would therefore stand behind the plate, step forward to the center of the plate, and immediately initiate the jump. With the necessity of stepping forward and quickly performing the jump:

   a. the subject might not have stepped to the center of the force plate;
   b. optimal concentration, body position, and technique might have been sacrificed because of the need to hurry.

The small size of the force platform (1 meter by 1 meter) might have inhibited some subjects' maximal effort for fear of landing on the platform edge.

3. USE OF ELECTROMYOGRAPHY. The electrodes on the rectus femoris might have inhibited a full arm swing for fear of catching the wires.

Intersubject comparison of integrated EMG is not possible; for the placement of electrodes, thickness of the skin, depth of adipose tissue, and other extraneous variables affect the strength of the electrical

potential.(60). It is a valid comparison, though, to compare pre-test values to post-test values on the same subject.

4. USE OF HIGH SPEED PHOTOGRAPHY. The expense involved in filming the jumps limited the filming to the pre- and post-test jumps only. The warm-up jumps were not filmed.

With the short duration of the jump, the film was often accelerating or decelerating. This made it impossible to calculate the area under the curve in the force plate measurements.

The peak force was thus used in the force plate analysis; with the limitation being that at 100 frames/second, it is possible to miss the peaks.

Calculation of the height jumped using the film and the digitizing board might have a 7 to 20 per cent error involved.(7). However, this is still much more accurate than other methods of measuring the height jumped.

In developing the film, the film of the oscilloscopes and IEMG had to be "pushed" two times to allow enough light. This affected the resolution, and, as a result, the IEMG readout could not be read.

5. USE OF WEIGHT BAR FOR RESISTANCE. Some specificity was lost when warming up with the bar, for the arms were not free to swing.

6. PSYCHOLOGICAL FACTORS. The novelty of the testing apparatus, peer pressure from other subjects, and other psychological factors were impossible to control and might have affected performance.

7. PHYSICAL FACTORS. Physical factors such as previous activities, diet, and amount of sleep were uncontrolled but were often noted.

Limitations (for the shot-put experiment)

1. SUBJECT SELECTION. There were very few highly skilled shot-putters in the Edmonton area. Therefore, some lower skilled subjects were included in this study (i.e. 8-9 meter put for female). The analysis of improvement was clouded by the inconsistency in performance by these more novice competitors.

2. USE OF SHOT WITH LARGER CIRCUMFERENCE. The women used a 12 pound shot in their overload warm-up. A 12 pound shot has a slightly larger circumference than the regulation 8 pound shot and might have caused some problem in grip. The men used a shot that was heavier without an increase in circumference.

3. MEASUREMENT PROCEDURE. The testing was conducted in the Kinsmen Field House (which has a rubber surface) using an indoor shot. The shot left no lasting mark on impact, and the accuracy of measurement was thus dependent on the tester closely watching the exact poing of impact.

4. PSYCHOLOGICAL AND PHYSICAL FACTORS. (As per limitations #6 and #7 in the jumping experiment.)

Definition of Terms

Overload warm-up: preparation for an event whereby resistance is added to the movement being performed.

Power: rate at which work is performed. $P = \frac{W}{t}$; P = power developed, W = the work done; t = the time taken. (45)

Impulse: a vector quantity; the product of the force and the time for which it acts.(45) The total impulse on a body is equal to the total change in momentum of the body.(20) $I = F \times t$, I = impulses, F = force, t = time during which the force acts.

Vertical jump: refers to a jump for maximal height which is from a stationary position with the feet side by side about six inches apart.

Force Platform: a device which in this case was used to measure the vertical component of force.

Electromyograph (EMG): an EMG is basically "a high gain amplifier with a preference or selectivity for frequencies in the range of about 10 to several thousand Hz (cycles per second)". (5) An EMG thus measures the electrical discharge within muscle tissue.

Integrated EMG: an EMG signal can be integrated to simplify the recording by taking the variables of amplitude, frequency, and spike shape and providing an arbitrary quantitative figure.

Shot-put: a standing shot-put was used in the controlled experiment while in the supplementary shot-put experiment, the subjects included the glide phase in their puts. The shot, a metal ball, has to be put from the shoulder with one hand. When starting the put, the shot has to be in proximity of the chin. During the put, the arm must not be lowered, and the shot must not be brought behind the shoulder line.(93)

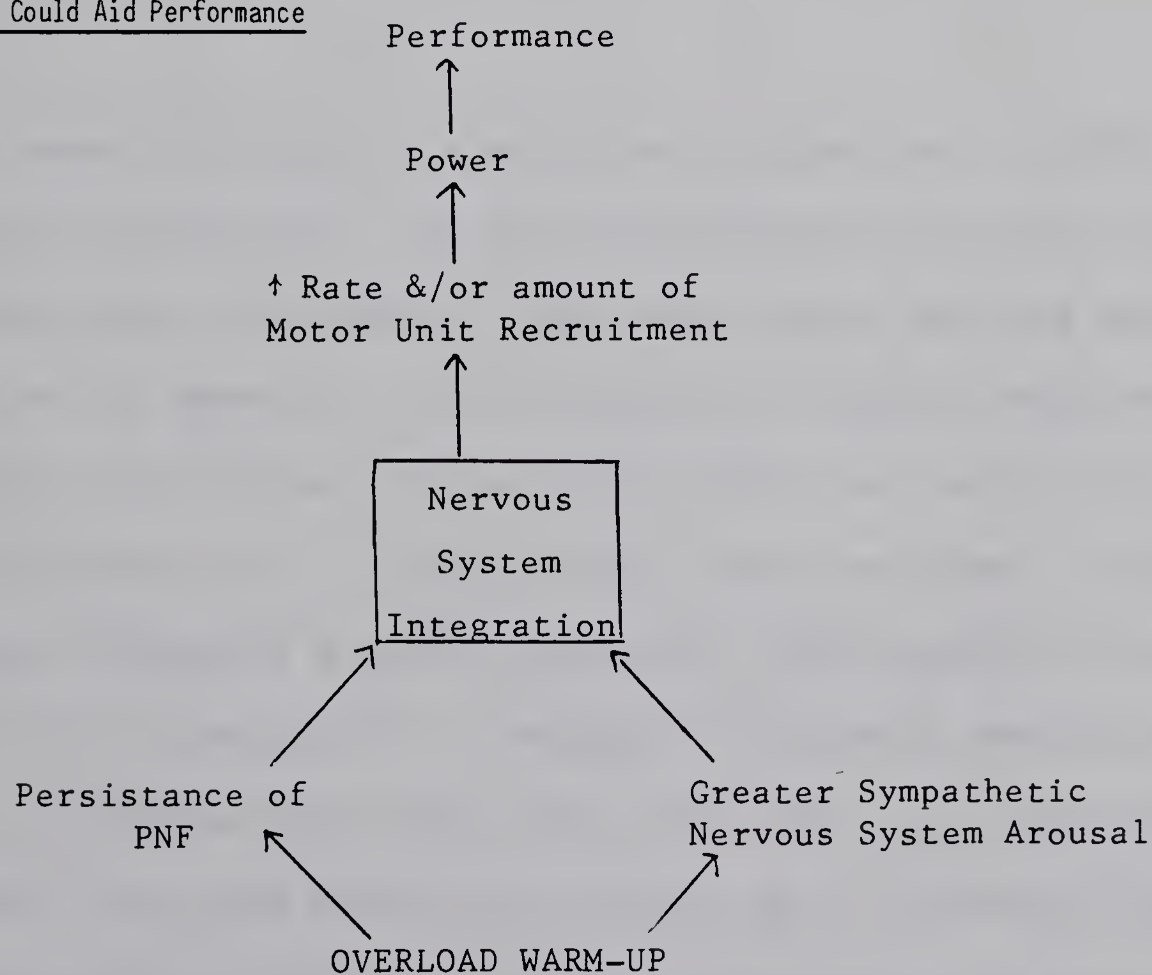
CHAPTER II

REVIEW OF LITERATURE

Introduction

The concept of power was addressed in the introduction. Through neuromuscular origins, an overload warm-up could possibly induce a greater number and/or rate of motor unit recruitment which would lead to increased power. The review of literature will identify the means to this as either persistence of proprioceptive neuromuscular facilitation (PNF) or greater sympathetic nervous system arousal. Both could theoretically be manipulated in an overload warm-up to enhance motor unit recruitment. To understand these possibilities, the black box of nervous system integration must be illuminated.

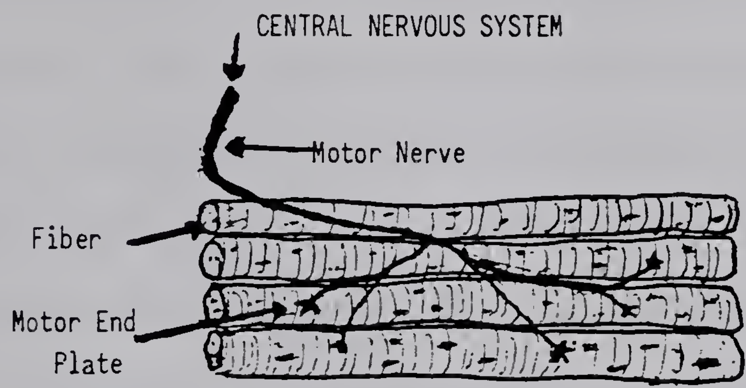
Figure 2: The Means By Which An Overload Warm-Up Could Aid Performance



The Motor Unit

The motor unit is the basic unit for all movements, for it is the smallest subdivision of the muscle which can undergo a conscious contraction. The motor unit includes the nerve cell body, the long axon of the motor nerve, its terminal branches, and all of the muscle fibers supplied by these branches.(6)

Figure 3: The Motor Unit of Skeletal Muscle



Copied from Mathews & Fox (75)

The number of fibers in a motor unit varies from 2 to 2000 depending on the type of muscle.(2). In the rectus femoris, the muscle examined in this study, there are primarily large motor units, while in muscles where fine control is important, such as the eye or fingers, small motor units predominate. The minimum tension that a muscle can exert is the tension of its smallest motor unit. Large and small motor units may be uniformly distributed throughout a muscle, and muscle fibers making up a motor unit may be widely dispersed.(29) A strong contraction of skeletal muscle requires the contraction of many such motor units. An asynchronous volley of impulses, with each motor unit twitching up to 50/second, results in a continuous shower of twitches allowing a smooth pull by a muscle.(5).

Through EMG analysis, a number of researchers have studied the changes in motor unit recruitment with modifications to force output.(3,4,33,40,47,

48,53,61,80,82,96,99,112) The central nervous system has a choice of modifying the output of a muscle by varying: (1) the number of motor units recruited per unit of time, (2) the kind of motor units recruited, or (3) the frequency at which a motor unit will be activated.(33)

Person and Kudina (89) have found that the degree of synchronization seems to be related to the intensity of contraction, and that asynchronous motor unit activity takes place only during very weak contractions. Training for explosive power has been shown to bring about a more synchronous firing of motor units and/or increases the number of motor units recruited.(3,33).

The more fatigue resistant units are more likely to be activated before the fast twitch fatigable motor units.(47) As the muscular effort is increased in force and speed, the relative importance of the fast twitch (power fibers) becomes increasingly greater. With increased input to a motor neuron pool, larger units are recruited; therefore, large motor units which have the greater energy expenditure will be used only in maximal muscular efforts.(112). The axons of larger cells have greater diameter, conduct faster, and supply many more muscle fibers than those from small cells. This bias for recruitment (i.e. fatigue resistant motor units first) also helps for a smooth gradation of force, for the slow twitch fatigue resistant unit has a small cell body. Normal voluntary gradation of force is accomplished by the initial recruitment of additional motor units followed by an increase in the firing rates of units.(57,63)

The largest contribution of motor unit recruitment occurs at low force levels, while the contribution of increased firing rate becomes more important at higher force levels.(82) This view, though, is contradicted by Clamann (21) and Person and Kudina.(89) Person states: "Recruitment is

undoubtedly the main reserve of contraction strength increase. However, the mechanism of frequency change is unsurpassed as far as precision and smoothness are concerned." Vrbova et al. (112) account for both of these viewpoints. Their observations revealed that, in muscles supplied by small motor neurons, the strength of contraction is increased by recruiting more motor units whereas, in muscles supplied by large motor neurons, tension is increased by their firing rate. Again there is a contradiction in the literature, as Kansove (57) reports that the major mechanism for controlling force in the large muscles of the extremities is recruitment of additional motor units. In smaller muscles where tension must be adjusted delicately, rate coding may be important. Additional motor units are also called into play when the fatigue phase of the bout is reached.(88)

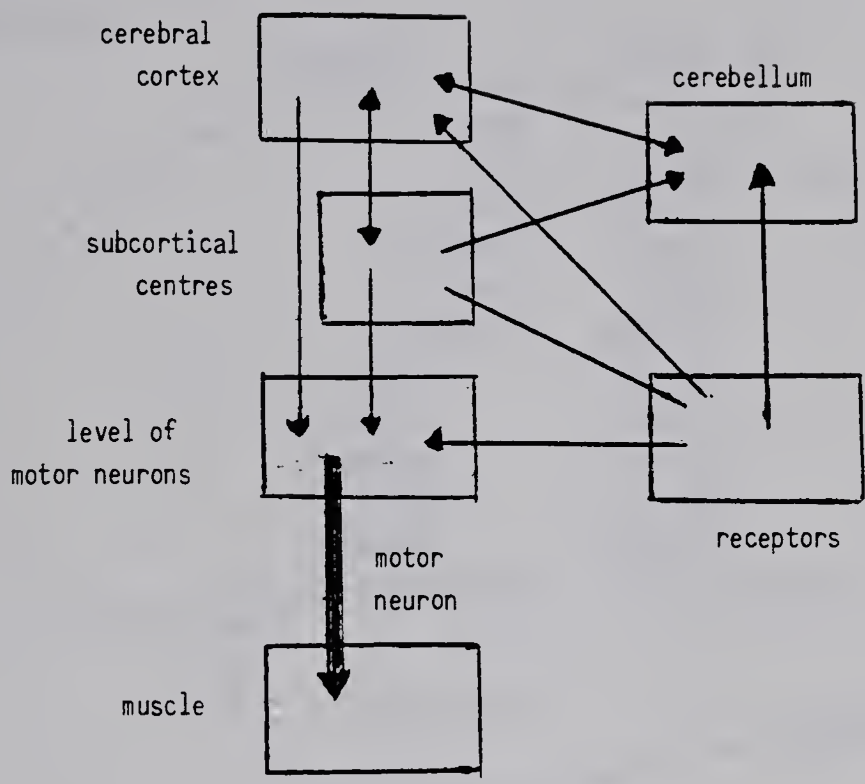
The recruitment order may follow a specific pattern in smoothly controlled contractions, but in strong contractions the order is not fixed. Proprioceptive feedback, particularly from muscle spindles, can change the threshold of motor units and thus change the order of recruitment.(40) Relaxation for up to one minute was often needed to re-establish the order. This is called facilitation through the gamma loop and will be discussed later.

Motor Control

The unique arrangement of cells and pathways in both motor and sensory systems provides a substrate for an extremely highly-developed control system for motor performance in terms of plasticity, flexibility, and refinement of function.(53) The coordination of movement, dependent on the interplay of muscles, (agonists, antagonists, synergists, and stabilizing muscles) is a complicated process. The cerebral cortex, cerebellum, subcortical centers,

and the receptors interrelate to converge on the motor unit to provide the speed, precision, and coordination to movements. Anything that affects the movement of skeletal muscle does so by means of synaptic input to the motor neurons. For coordinated movement, the different motor neurons involved should be excited or inhibited in the right order, to the correct degree, by appropriate frequencies, and at the right time.(112) The motor neurons are activated or inhibited by nervous impulses which constantly travel either through descending tracts from the brain or reflexly through sensory nerves in the muscles or other organs. The excitability of the motor neurons is dependent on the excitatory and inhibitory activity arriving at the synaptic knobs from different sources. The program for this movement, originating in the higher brain centers, is relayed in the form of action potentials to the motor neurons and on to the muscles. During the movement, proprioceptors from muscles, tendons, ligaments, and joints conduct sensory reports back to the central nervous system. Skin receptors, vestibular receptors, and receptors in the eyes are also detecting errors between program and performance. Any discrepancy between the original program and resulting movements is revised and corrected. A model of the interaction between the higher brain centers, the receptors, and the motor neuron is shown on the following page.

Figure 4: Diagram of Motor System Function

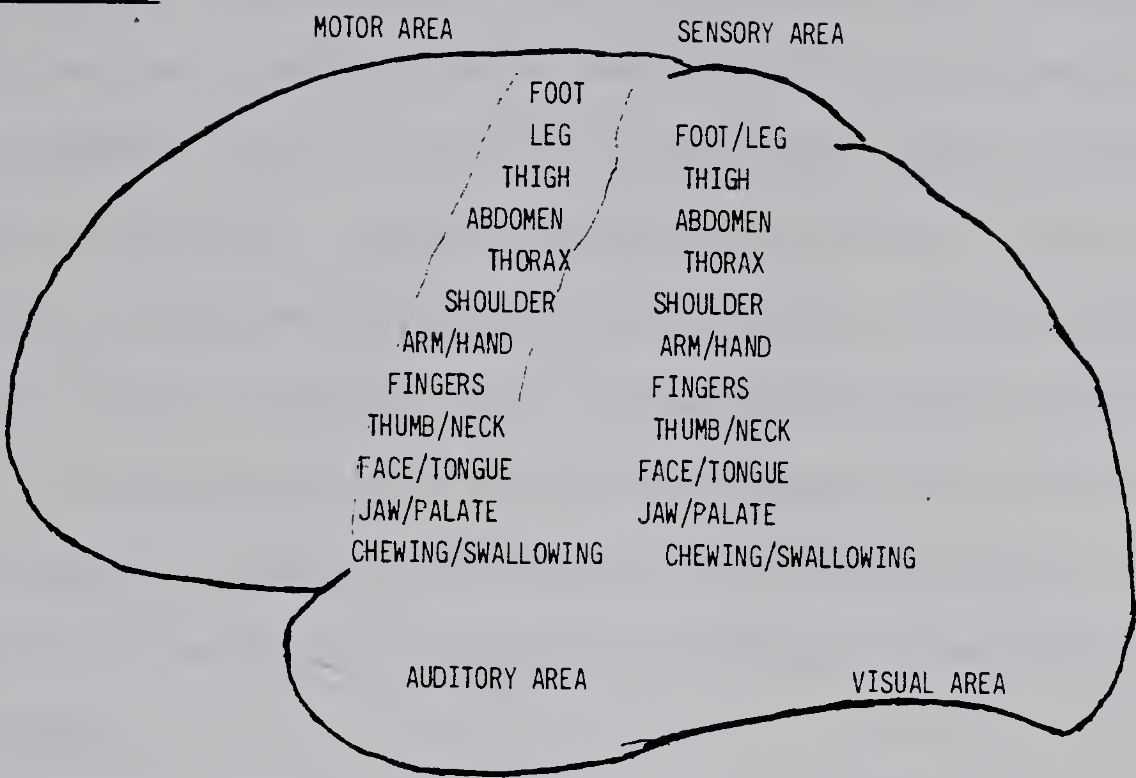


Copied from Vander et al. (109)

Volitional movements are initiated in the cortex; the rate and force of the contraction are controlled by the cerebellum.(3) The cerebellum receives information from peripheral receptors, and, while it does not initiate movement, it influences the motor cortex responsible for motor activity. The cerebellum will note any discrepancy between what the muscles should be doing and what the muscles are doing.

The motor cortex is a relay station receiving instructions from the cerebellum and putting them to effect via the motor neurons. As well, stimuli sensed by the receptors produce an excitation in certain areas of the motor cortex.

Figure 5: The Motor-Cortex



The motor area of the brain (cortex). The dark shading represents the pyramidal or Betz cells. Upon electrical stimulation to this area, motor movements are elicited — hence the term, primary motor cortex. Copied from Mathews & Fox (75)

When the stimulation is new to the body, as is the case when learning new movements, the excitation spreads to adjacent areas of the cortex as well. The results of this are seen in the uneconomic movements accompanying the first trials of a new movement. Practice tends to limit the excitation centers in the cerebral cortex, and only those muscles needed in the movement are called into play.(93) The proper sequence of movements is stabilized with further practice. Through learning then, a complicated pattern of muscle movements can be shifted from the highly conscious end of the spectrum over toward the involuntary end. Movements are eventually performed "automatically". Automatic movements, or programs of particular motor patterns, can be called upon in the execution of a skill and the program is immediately "replayed". Hannerz (43) concluded that normal man can

select in advance the recruitment order of motor units most appropriate for the work intended. Rapid movements can be pre-programmed in their entirety, for there is no time to modify the action during the performance. Pre-programming requires calculation of the time needed, amount of force needed, and distance to be moved. This could be called task set.(100) While it is known that the cerebellum is largely responsible for the unconscious programming of motor movements, it is not known how a given program is selected. Fox and Mathews (75) write that programs would consist of a set of non-conscious instructions that direct the necessary nerve impulses to the appropriate muscles in a coordinated sequence, thus causing the desired movement.

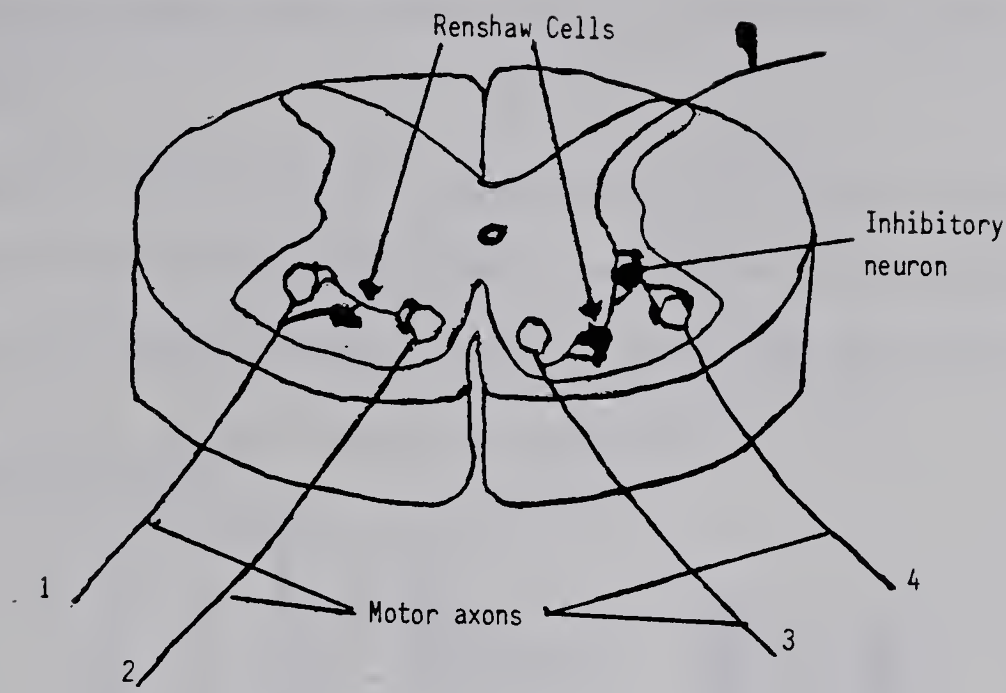
The pyramidal tracts are the paths used to send impulses from the motor cortex down to the anterior motor neurons of the spinal cord. The complexity of the pyramidal tract is shown by the fact that, in humans, the tract contains about 1.2 million fibers.(109) The pathway from the cortex synapses in the basal ganglia, brainstem nuclei, and brainstem reticular formation. These synapses serve to control postural mechanisms and coordination of the many simultaneous movements of locomotion. Most neural control of skeletal muscles is reflex in nature. Pavlov (93) and Conrad (22) explain that coordinated movement is a chain of successive reflexes of which the conditioned reflexes are of the main interest. When an afferent impulse enters the spinal cord and synapses with motor neurons going back to the muscles, a reflex arc is completed. Reflexes are the response of the body to external and internal stimuli. Conditioned reflexes are acquired, subject to changes, and limited in time.

Generally, several connecting interneurons intervene between the afferent

and efferent neurons. Most of the pyramidal tract fibers from the cerebral cortex area terminate on interneurons. The intervening interneuron can give rise to excitation or inhibition. Astrand (2) points out that, via interneuronal circuits, information based on past experiences will permit modification of responses. Present experiences can also modify the response. Vallerga (107) found that louder sounds produced faster arm movements and stronger contractions of the muscles. It was postulated that greater perceived stimulus intensity results in stronger excitation of the pyramidal tracts and consequently more forceful muscular contractions. A stronger excitation of the pyramidal tract is possibly due to disinhibition of the motor neurons.(2) This involves the Renshaw cells and other inhibitory interneurons. Renshaw cells can depress the activity of the inhibitory neurons and free the motor neurons from inhibition.(2) Inhibition is thus inhibited.

If the Renshaw cells synapsed with excitatory interneurons, the effect would be an inhibitory barrier, and only the strongly excited neurons would penetrate this barrier.

Figure 6: Motor Control Through Renshaw Cells



Some motoneurons give off branches, called recurrent collaterals, before they leave the gray matter of the spinal cord. These collaterals synapse with inhibitory interneurons named Renshaw cells. They synapse in turn with the same or other motoneurons. To the left in the figure, the activated motoneuron (1) stimulates the Renshaw cell, which then inhibits both motoneurons (1) and (2). To the right, we have an example of inhibition of inhibition: an impulse in the afferent nerve stimulates the inhibitory neuron, and therefore, the motoneuron (4) will become inhibited; if the motoneuron (3) is now stimulated, it excites via its recurrent collaterals the Renshaw cell, which in turn inhibits the inhibitory neuron, and as a consequence, the motoneuron (4) will be released from the inhibition and may more easily respond to excitatory impulses. *(Inhibitory neurons are shown in black.)*

Copied from Astrand & Rodahl (2)

In conclusion, both sensory feedback and central command interrelate to provide motor control.

Proprioceptors

Much of the control of muscle activity arises from receptors within the muscle or tendons themselves. Afferent output from these proprioceptors informs the central nervous system about muscle length and tension. This information may be used in purely local reflexes or can be transmitted to higher brain centers where it can be integrated with input from other receptors.

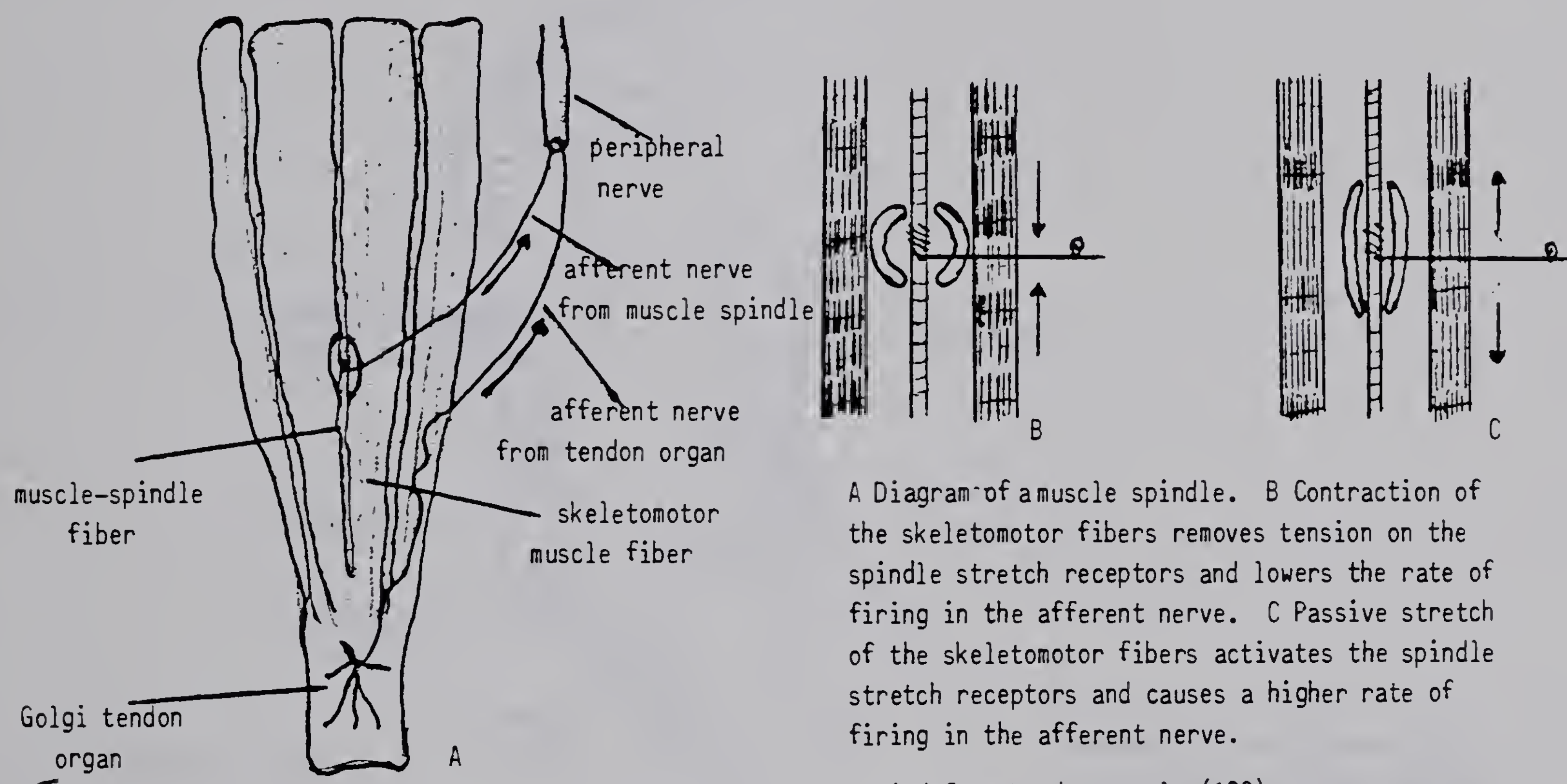
A. MUSCLE SPINDLES. Embedded within the muscle and of muscular origin are

mechanoreceptive afferents called muscle spindles.(106)

Muscle spindles may modify impulse rates in a number of different ways.(105)

Passive stretch of the entire muscle stretches the spindle fibers which activates their receptors. Contraction of the skeleto-motor fibers releases the tension on the spindle fibers and would thus slow down the rate of firing of the stretch receptor.

Figure 7: The Muscle Spindle



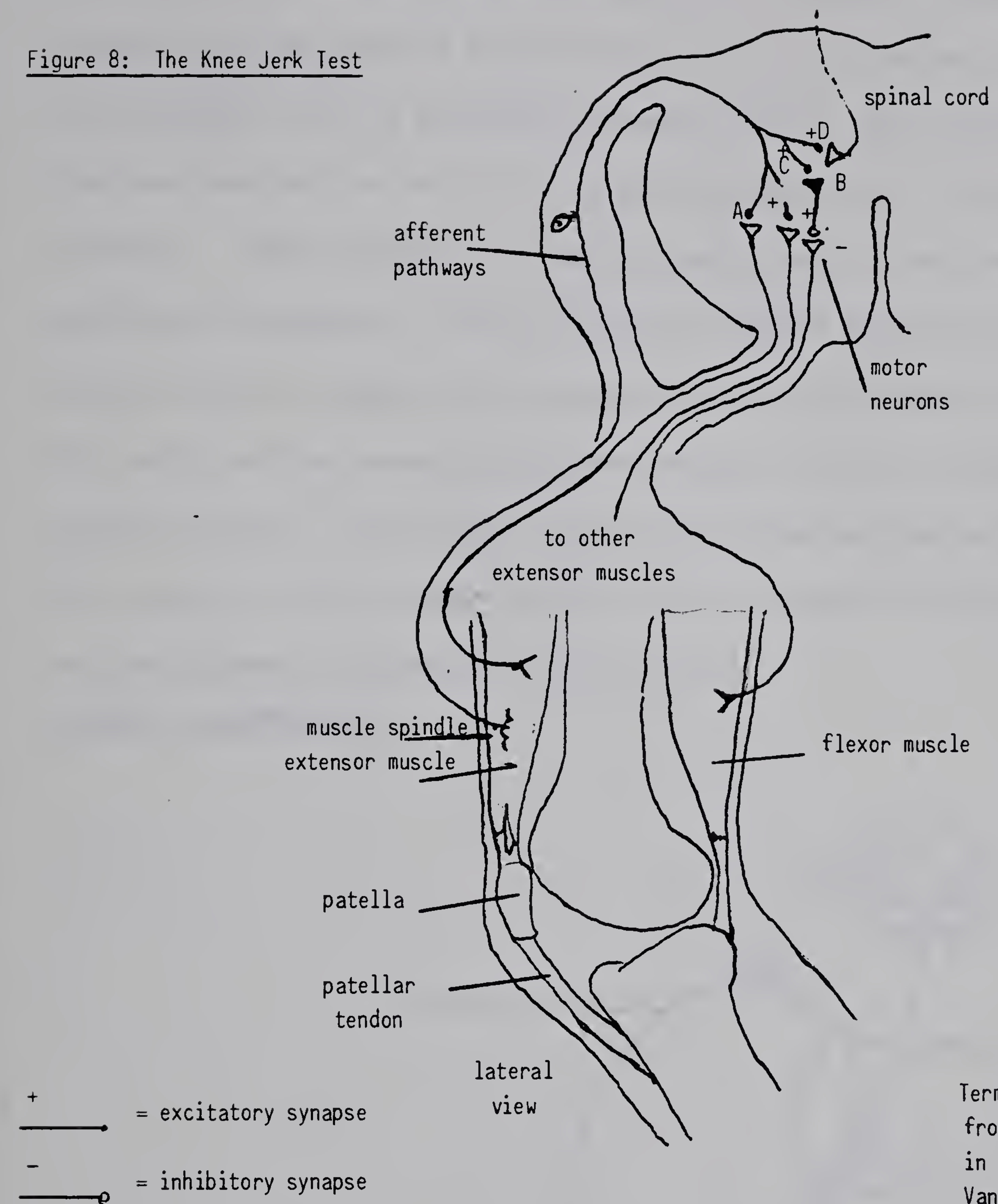
A Diagram of a muscle spindle. B Contraction of the skeletomotor fibers removes tension on the spindle stretch receptors and lowers the rate of firing in the afferent nerve. C Passive stretch of the skeletomotor fibers activates the spindle stretch receptors and causes a higher rate of firing in the afferent nerve.

Copied from Vander et al. (109)

Because there are different types of spindle receptors,(14) muscle spindles can also respond to the magnitude of stretch and the speed with which it occurs. This information allows the CNS to anticipate the magnitude of stretch.

The reciprocal arrangement between agonist and antagonist controlled by discharges from the muscle spindle can provide for smooth adjustment to rapid changes in the external environment without considerable temporal delay. This can be demonstrated with the stretch reflex as shown in the knee jerk test.

Figure 8: The Knee Jerk Test

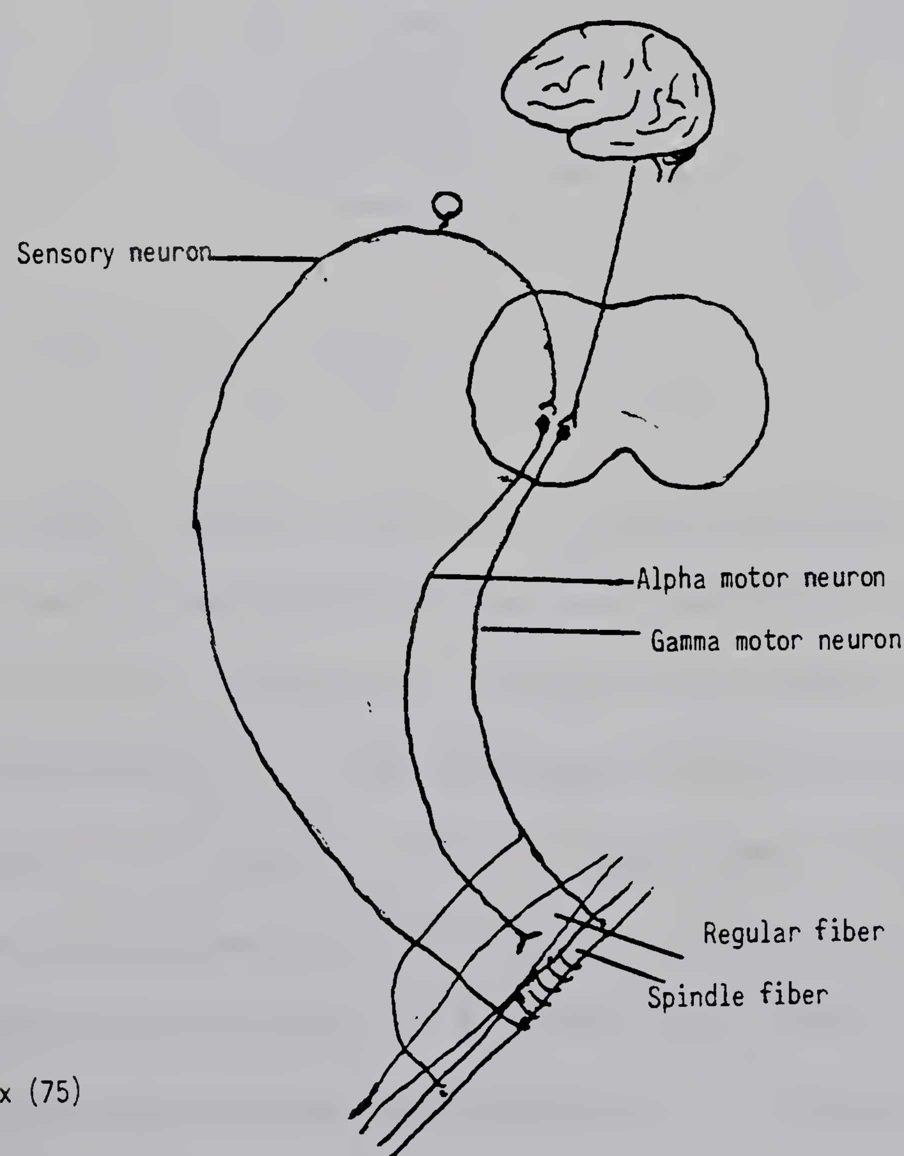


Terminals of the afferent fiber from the muscle spindle involved in the knee jerk. (Copied from Vander et al. (109)

Here, the patellar tendon is given a quick forceful tap. This stimulates the spindle, and information is relayed through the reflex arc, and a contraction of the quadriceps is initiated. In order for movement to occur, the antagonist of the stimulated muscle must be inhibited simultaneously. This is seen with the afferent terminal "B" in the diagram above and is called reciprocal innervation. As well, the reflex will stimulate synergistic

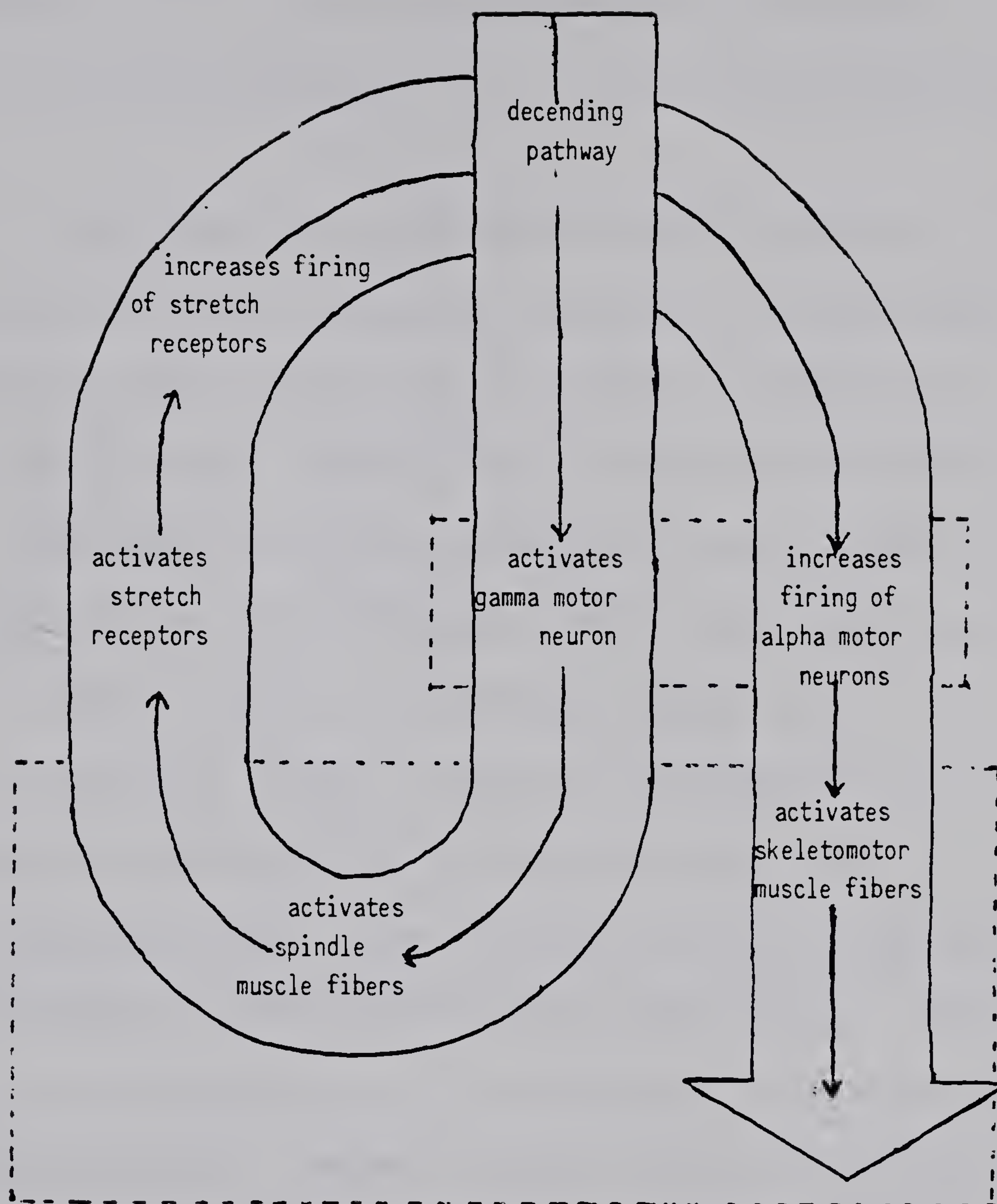
muscles "C" to assist the reflex motion. Finally, information about muscle length would be sent to areas of the brain dealing with coordination of muscle movement ("D" in preceding diagram).(109) The spindle fiber itself can contract and this also aids in providing effective coordinated and smooth movement. The contractile ends of the spindle fibers are innervated by gamma motor neurons. Activation of the gamma fibers from the cerebral cortex does not cause any increase in muscular tension but does stretch the outer portion causing afferent output from the spindle. Like the stretch reflex, this output can in turn stimulate alpha motor neurons which will contract the skeletal muscle. This system is called the gamma loop or alpha gamma coactivation.(2,3,75,109)

Figure 9: The Gamma Loop (A)



Copied from Mathews & Fox (75)

Figure 10: The Gamma Loop (B)



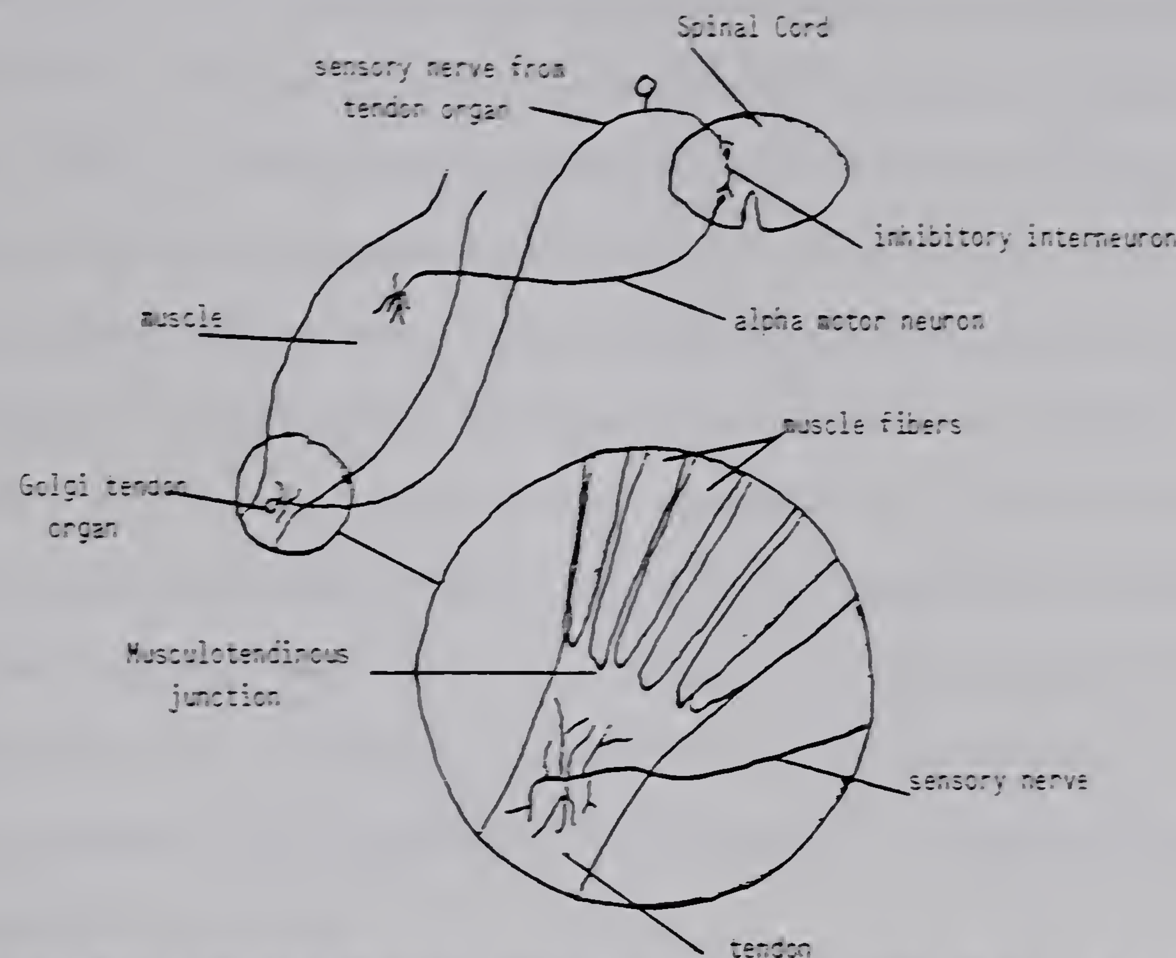
Gamma loop. The small rectangle at the centre indicates those effects occurring in the brainstem or spinal cord; the large rectangle, the effects in the muscle.
Copied from Vander et al. (109)

The importance of this system is that if the spindle stretch receptors were permitted to shorten at the time the large skeletal muscle fibers shortened, the receptors would discontinue firing action potentials and afferent information would be lost. This continued monitoring could, for example, cause summation of contraction with the recruitment of additional motor units if the load proved heavier than planned. Conversely, it could dampen too intense alpha motor activity if the load was lighter than expected. The gamma loop may have limited effect on immediately increasing power, but

a facilitatory effect on later jumps may take place. The direct pathways are probably more important in skilled and sudden movements, whereas the gamma loop may be more important for postural control and automatic movements such as walking.

B. GOLGI TENDON ORGANS. While muscle spindles monitor both the rate of change in length and the final length attained by the muscle fibers, another proprioceptor, Golgi tendon organs, monitor tension. These receptors are encapsulated in tendon fibers and are located near the junction between the muscle and the tendon. They sample the force produced by a small number of motor units.(106) Similar to the muscle spindles, Golgi tendon organs are activated by the stretch placed on them. In contrast, though, to the spindles which are facilitatory (i.e. cause contraction), stimulation of Golgi tendon organs results in inhibition of the effector muscle with reciprocal excitation of the antagonist. They, therefore, serve a protective function if the load on a muscle is too great and could cause injury. This protective inhibition, as was mentioned in the introduction, is possibly the limiting factor in power testing.(75) Maximal strength would be dependent upon the ability to oppose voluntarily the inhibition of tendon organs.

Figure 11: The Golgi Tendon Organ



The Golgi tendon organ. When a contracted muscle is forcefully stretched, the sensory nerve of the tendon organ is stimulated. Impulses are sent to the spinal cord, where a synapse is made with an inhibitory interneuron that inhibits the alpha motor neuron, and the muscle relaxes. Copied from Mathews & Fox (75)

Golgi tendon organs have varying thresholds and function as more than just safety valves. They are able to supply continuous information about the tension generated.(106) This allows for coordinated movement, for it tells the CNS how many motor units should be recruited. The motor "program" may have to be altered, because the tension developed by a contracting muscle by a preset number of motor units is not always the same. The tension developed depends on the velocity of muscle shortening, the muscle length, the degree of muscle fatigue, in addition to the number of activated motor neurons, and the rate at which they are firing.

Proprioceptive Neuromuscular Facilitation

A technique by which output from the proprioceptors can facilitate (or inhibit) activity in the motor units is called proprioceptive neuromuscular facilitation (PNF).(17) PNF techniques were introduced around the late 1940's (27) and are based on maximal excitation or inhibition of the motor nerve cell body through central mechanisms. This is done through the precise use of maximal resistance to patterns of movement in a sequence of muscular contractions.(27) PNF techniques are most prevalent in a rehabilitative setting where they have aided in producing skillful coordinated action with sufficient strength and range of motion to be of functional value.

PNF makes use of the following neurophysiological mechanisms to increase CNS excitation or inhibition: (1) reflexes, (2) irradiation, and (3) successive induction.

Reflexes may be used to activate or inhibit a maximum number of motor nerve cell bodies, or to initiate motion which may be brought under voluntary control after practice. Successive induction augments a reflex by utilizing the opposite neural pathway; for example, immediately after the flexion reflex is elicited, the excitability of the extension reflex is greatly increased.(27)

Irradiation refers to the spread of excitation in the central nervous system which results in the contraction of all muscles used in a specific pattern. This increased response is also called reinforcement. Decker (27) writes:

> Irradiation occurs in reflexes when the stimulus is strong, and in voluntary motion when there is resistance which may be applied manually in the case of facilitation techniques, and by frictional or gravitational forces in the case of stress situations in ordinary activities.

Reinforcement progresses to adjacent muscles with increased stimulation and irradiation. Valbo (105) found that the afferent impulses from the spindles in one muscle may influence the excitability of motor neurons innervating several other muscles. Resisted contraction of the stronger muscles within a specific irradiation pattern constitutes a powerful proprioceptive stimulus which facilitates reinforcement of weaker muscles. Martiniuk (71) explains that muscle tension could feedback to the reticular muscle activating system which is located in the subcortical, reticular formation of the brain. The ascending reticular activating system plays an important role as the source of a generalized drive state. In order for PNF techniques to bring about the desired effects the positioning and timing of resistance must be precise. Reinforcement may also occur with an auditory stimulus. Burg (14) discovered that the stimulation of a hand clap, which activates reticular structures, produced a well-marked and long-lasting facilitation of muscle spindles.

How long can proprioceptive neuromuscular facilitation persist? Many researchers have noted a persistent change in afferent discharge following stimulation.(1,14,22,34,47,48,104)

Early researchers in this field were Hunt and Kuffler (cited in 34). In 1951, they noticed that spindle excitation was sometimes followed by a persisting elevation of the discharge and enhanced sensitivity to subsequent gamma efferent stimulation. The "post excitatory facilitation" disappeared following a brief stretch, and they suggest that it was due to some physical change in the intrafusal fibers.

Fifteen years later, Brown et al. (cited in 34) studied the post excitory effect in single efferent fibers following stimulation of dynamic and static fusimotor fibers. Both dynamic and static fibers produce a

greater discharge and stretch sensitivity. Brown elaborated on Hunt's and Kuffler's explanation by suggesting that, following contraction of the intrafusal fibers, persistence of cross bridges between actin and myosin filaments might leave the motor poles somewhat shortened and stretch the sensory ending. Extrafusal muscle rigidity following contraction has also been explained by the concept of residual cross linkages. Martiniuk (71) thought it was possible that preliminary muscular tension could take up the slack in the muscles responsible for a reaction movement, thus shortening the time to respond.

Kidd (1964) and Hnik et al. (1972, 73) (cited in 34) proposed a different explanation to account for persistent afferent discharge. They suggested that K^+ ions released into interstitial spaces during contraction might have partially depolarized the sensory endings and led to the acceleration in discharge.

Eldred et al.(34) reviewed the nature of the persisting changes in afferent discharge from muscle following its contraction and arrived at these conclusions:

1. A persisting increase in discharge at a maintained muscle length and in response to stretch appears after a muscle has undergone contraction.

2. Fusimotor activation alone, for example, contraction of intrafusal fibers, can produce this effect, although extrafusal contraction appears to contribute. It was found that a higher stimulus strength was decidedly more effective in increasing the activity of the spindles.

3. The cause of the after-effect is probably of a mechanical nature. Eldred rejected the K^+ explanation for a number of reasons. Stretching resulted in the disappearance of increased discharge, and the duration of

the stimulus needed for response is only a few tenths of a second. It was doubted that excitatory levels of K^+ would build up in this time. If the muscle was undisturbed, the effect could last several minutes. K^+, though, should be swept away more quickly than this. Post-contraction effects are intensified when the stimulus rate is increased above the tetanic fusion frequency. In this situation, there should be no additional K^+ release from extrafusal fibers.

While Eldred felt that residual cross linkages were likely to account for an increase in discharge of considerable volume, persist for many minutes, and resist several millimeters of muscles stretch, he noted that more than one factor may be at work. For example, some change in gross muscle alone may lead to the changes. In muscles like the gastrocnemius, the slower motor units (and spindles) predominate in the central portions of the muscle, so that this region relaxes more slowly after tetanus than the periphery. This would leave the muscle in a slightly different arrangement of connective tissue and muscle fasciculi after contraction than when the muscle relaxes after an imposed stretch. Some alteration in geometry or rigidity within the muscle must occur, since, after tetanus, there is usually a small residual elevation in tension.

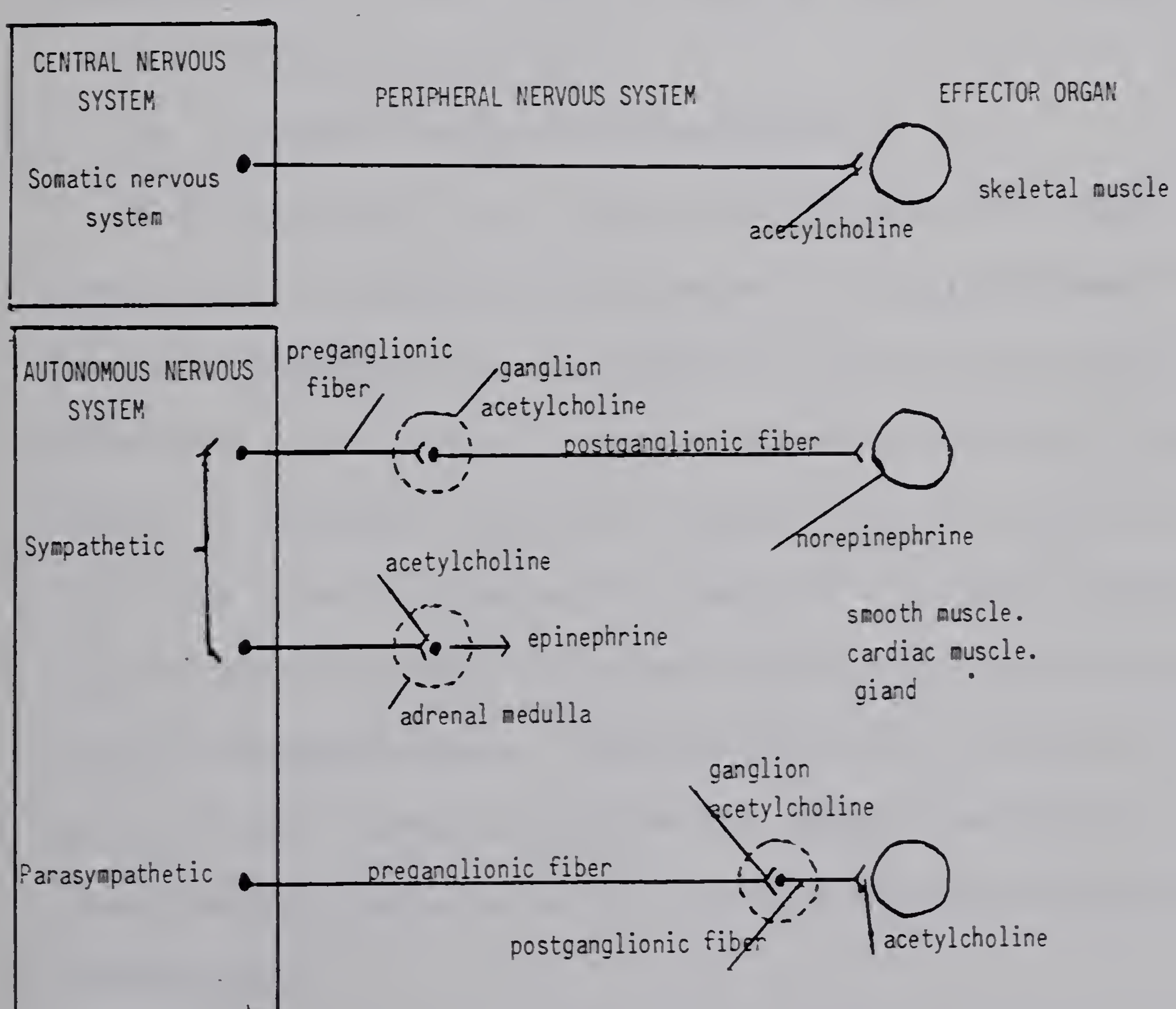
Sympathetic Nervous System

While jumping with weights could theoretically supply a strong proprioceptive stimulus, which facilitates irradiation and thus a more powerful muscular contraction, the sympathetic nervous system may also be enhanced by this regimen.

The sympathetic nervous system is a division of the autonomic (involuntary) nervous system. The autonomic nervous system (ANS) is involved in all aspects

of stress physiology.(13) The sympathetic division acts reciprocally to the parasympathetic and is responsible for the "fight or flight" responses during alarm or before and during exercise. Acetylcholine is released by both the sympathetic and parasympathetic ganglionic synapses between the pre- and post-ganglionic fibers. The chemical transmitter between the parasympathetic post-ganglionic fiber and the effector organ is also acetylcholine. The sympathetic post-ganglionic fiber releases norepinephrine. As well, the sympathetic system can activate a hormonal response by sympathetico-adrenomedullary activity. The adrenal medulla releases a mixture of about 80 per cent epinephrine and 20 per cent norepinephrine into the blood. The divisions of the nervous system are shown below.

Figure 12: Efferent Divisions of the Peripheral Nervous System



Copied from Vander et al. (109)

Sympathetic activity prepares the body in a number of ways to face stressful situations (2):

1. Increased hepatic and muscle glycogenolysis (provides a quick source of glucose).

2. Increased breakdown of adipose tissue triglyceride (provides a supply of glycerol for gluconeogenesis and of fatty acids for oxidation).

3. Increased central nervous system arousal and alertness.

4. Increased skeletal muscle contractility and decrease of fatigue.

5. Increased cardiac output secondary to increased cardiac contractility and heart rate as well as increased venous return (venous constriction).

6. Shunting of blood from viscera to skeletal muscles by means of vasoconstriction in the former and vasodilation in the latter.

7. Increased ventilation.

8. Increased coagulability of blood.

Points #3 and #4 are of particular interest when considering immediate power gains. It is believed that a center in the hypothalamus acts, via descending pathways, upon the medullary centers (and directly upon the sympathetic vasodilators to skeletal muscle arterioles) to produce the changes in autonomic function so characteristic of exercise. It is further speculated that the same motor areas of the cerebral cortex, which are responsible for the skeletal muscle contraction, give off branches to trigger the hypothalamus. This hypothesis was the result of a finding that electrical stimulation of certain hypothalamic areas in resting unanesthetized dogs produces all the cardiovascular changes observed during exercise.(109)

Can any exercise or manoeuvers increase the outflow of sympathetic

impulses to the muscles? Hahner (42) thought it was entirely feasible that ANS activity could be altered through physical conditioning. He measured ANS reactions to stress with a number of subjects and found that the most successful athletes had the highest autonomic scores. Autonomic conditioning was concluded to be a reality, although closely defined types of physical conditioning remain unknown. It has been noted (106) that any manoeuver or situation associated with an altered blood pressure is likely to produce a change in the sympathetic activity in muscle nerves. For example, the Valsalva manoeuver (a forced expiration against a closed glottis) usually leads to a marked fall in blood pressure and an increase in sympathetic activity to the muscles.(106) Although decreased blood pressure usually appears to increase sympathetic activity, the relationship does not always hold true. Emotional stress can sometimes lead to an increased nerve activity at the same time as the blood pressure goes up. The question of designing manoeuvers to increase sympathetic activity is complex since most manoeuvers themselves are complex and involve several kinds of stimuli. Valbo (106) concedes that one should probably expect "the final effect of a manoeuver on the sympathetic outflow to be determined by a complicated interaction of a number of reflexes and cortical influences, the relative strength of which may vary between subjects and from one manoeuver to another."

One could also question if increased sympathetic activity can aid skilled motor performance. Motor performance may follow an inverted "U" curve trend with increases in muscular tension.(71) There is probably an optimal range of sympathetic activity for various types of performances. Simple reaction-time movements may be enhanced by high sympathetic tone, while more complicated, technical activities (e.g. golf swing) may be impaired by high sympathetic

activity.

It will take further study to determine if jumping or shot-putting with overload enhances sympathetic activity which leads to increased muscle contractility.

Warm-Up

It has thus far been suggested that power could be increased through two different mechanisms associated with an overload warm-up: (1) persistance of a proprioceptive neuromuscular facilitation effect and/or (2) increased sympathetic tone. For the purpose of practical application, the experimental design should allow evidence that, not only will performance be improved by an overload warm-up, but that the improvement is superior to that arising from a non-overload warm-up.

The value of a warm-up has been extensively studied with various considerations: specificity (11,30,59,66,78,95,101), intensity (59,78,79,86), duration (59,79,92), psychological preparation (59,74,84,103), and overload (11,14,83,84,85,90,98,110), with the major criteria being performance (39,59) (speed (14,66,67,84,90,91,101,110), accuracy (14,83,90,101,110), endurance (83,101), power (11,79,83,86,91,98)). Injury prevention and muscle soreness (59,95) have also been considered in relation to warm-ups. Although there is some conflict in the literature, the consensus appears to be that a warm-up can improve performance, and that a specific warm-up of moderate duration (15-30 minutes) and graduated intensity is best.(59)

Any warm-up which increases muscle temperature allows metabolic processes in the cell to proceed at a higher rate, since these processes are temperature dependent.(2) For each degree of temperature increase, the metabolic rate in the cell increases by about 13 per cent.(2) As well, the nerve messages

travel faster.(2,38) Human nerve impulses travel up to 8 times faster than those of a frog due to our much higher body temperature.(2) The introductory part of a training or competition session prepares the athlete for the principle tasks to be tackled. Adhering to the principle of specificity, the warm-up should stress those systems, muscles, and movements that will be used in the activity.(93) A typical warm-up procedure for a vertical jump would therefore be a number of vertical jumps.

The overload warm-up would lose some specificity due to the added weight, but, as mentioned earlier, there are possible neuromuscular advantages gained through the overload. In the 1950's and '60's, a number of researchers experimented with the overload warm-up in events such as vertical jump (Stockholm) (98), throwing (Van Huss) (110), Petroff (90), Brose (14)), shot-put (Bishke) (11), bicycle riding, bat swinging, basketball foul shooting (Murray) (83), and simple resisted elbow flexion (Nelson) (84).

In the studies performed by Nelson, Bishke, and Brose, no improvement in performance was found with Nelson suggesting that there is simply a perceptual after-effect in the form of a kinesthetic illusion of increased speed created by the overload. Assuming motor unit activity to be the same during the pre- and post-overload trials, he felt that the subjects may have been comparing the speed of the post-overload trials with the overload trials instead of the pre-overload trials. The subjects may have been unable to remember what the pre-overload trials felt like. Despite the negative findings, Nelson thought that in some instances the associated kinesthetic illusion, if present, may prove to be an aid to performance.

Stockholm worked with Nelson on a later experiment with overload applied to the vertical jump. Again, no significant change in performance

was noted for the experimental group. There was a significant decrement though for the control group which led to their conclusion that an overload warm-up holds no positive effect but may prevent a decrement in performance. A fatigue factor was thought unlikely to account for the decrement observed for the experimental performances would also decrease. Stockholm suggested that the non-varying repetition of jumps with the control group caused their mental set to lapse in the later trials.

Petroff (90), Van Huss (110), and Murray (83) did find positive effects in using an overload warm-up. Petroff found a significant increase in baseball pitching velocity by fatigued throwers with no impairment to accuracy immediately following the throwing of an 11 ounce baseball. The regulation baseball is 5 ounces. Van Huss performed a similar experiment and concluded that an overload warm-up (throwing an 11 ounce ball) significantly improves the velocity of throwing. Although the majority of the subjects improved their velocity of throwing in this experiment, all subjects did not respond similarly or at the same rates. Van Huss also noted that the accuracy response following overload warm-up is altered. The overload warm-up impaired the accuracy in the first few throws following the warm-up, but this impairment was not significant.

Murray found that an overload warm-up aided batting swing speed while there was no effect on bicycle-riding, and basketball-foul shooting.

The inconsistencies in findings can probably be explained by the different movements and variety of types and levels of overload.

<u>Summary</u>

Two mechanisms of the nervous system have been identified which could theoretically be manipulated through an overload warm-up to enhance power

output:

1. Persistence of proprioceptive neuromuscular facilitation. The sensory output of proprioceptors in muscles and tendons when performing with overload could lead to a persisting increase in the rate and/or number of active motor units.

2. Sympathetic tone. The increased stress of an overload warm-up could enhance sympathetic activity which thus prepares the body for "fight or flight".

The nervous system is exceedingly complex, and the exact nature of many of its operations are just beginning to be understood.

CHAPTER III

METHODS AND PROCEDURES

The vertical jump experiment was conducted in the Strength Laboratory in the physical education building at the University of Alberta, while the shot-put experiment took place in the Kinsmen Field House.

Subjects

Eleven male and 11 female athletes were selected from the Edmonton area in the sports of track and field, volleyball, and basketball to participate in the vertical jump experiment. Selection was based on assumed skill in the vertical jump. The mean age and weight was 23 years and 79.2 kilograms for the males, 21 years and 66.2 kilograms respectively for the females, with the ages ranging from 17 to 30 for both groups. Two subjects, one male, and one female, were not included in the statistical analysis due to obvious inconsistencies in their jumping performance.

Ten Edmonton area shot-putters (5 males and 5 females) participated in the shot-put experiment. Their skill level ranged from 12 to 16 meters for males and 10 to 14 meters for the females. Their approximate age was 20 to 25 years although one 17 year old male participated.

Six of these same shot-putters (4 men and 2 women) took part in a supplementary experiment where they used an overload shot for the warm-up in an actual competition.

Apparatus

Electromyograph and integrated EMG. A Honeywell Electronic Medical System was used to record EMG's and IEMG's (see Appendix A).

Electrodes. Surface electrodes were used to pick up the electrical changes in the muscle. These electrodes were 2.5 centimeters in diameter and

consisted of a silver metal disc set into a plastic insulating cup. Electrode jelly was used to improve the electrical contact.

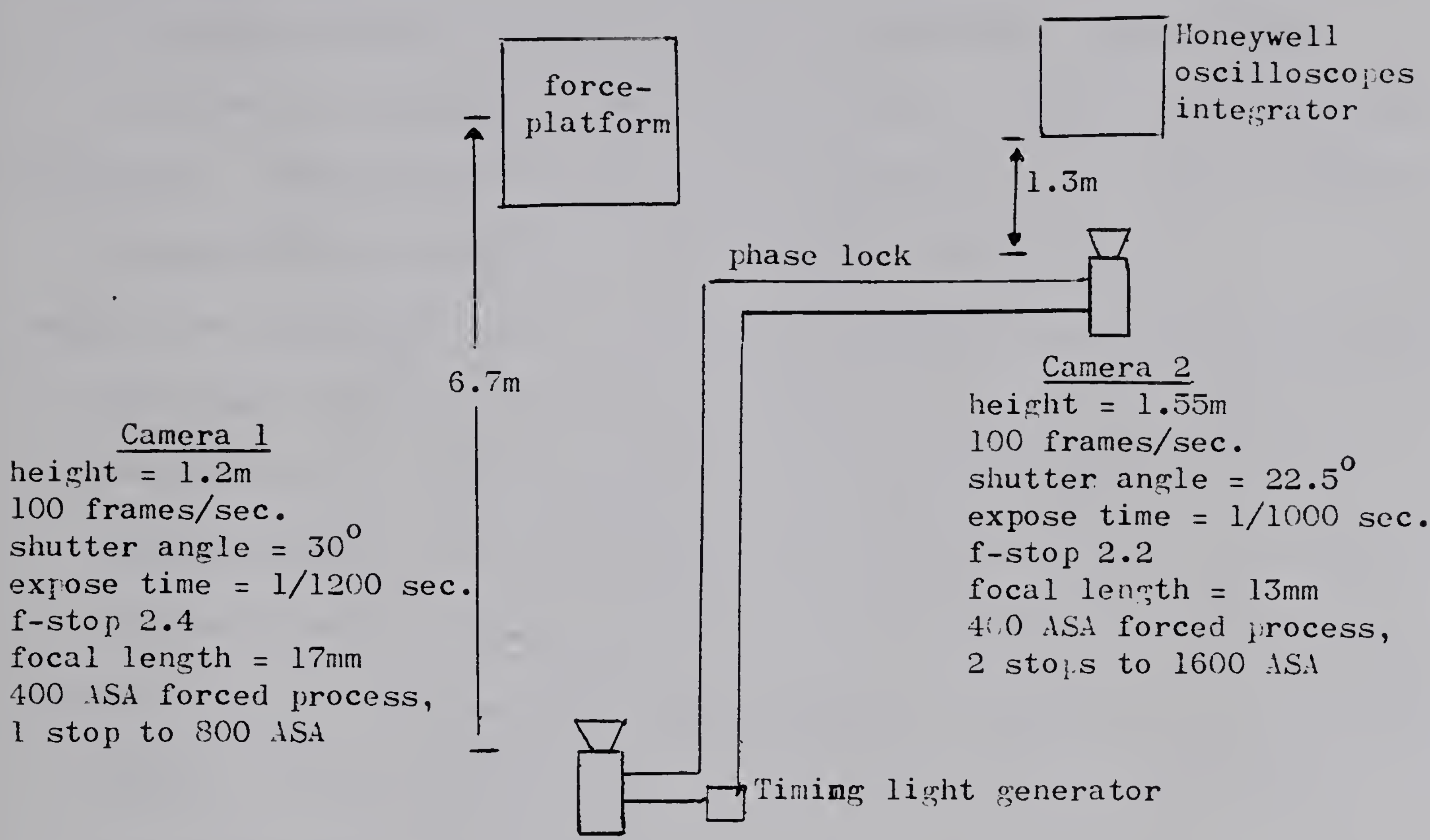
Force platform. A Stoelting's force sensitive platform (see Appendix B) measured the vertical impulse exerted by the subject during the jumps.

Oscilloscopes. The EMG and IEMG were displayed on the Honeywell oscilloscope. The IEMG also appeared on a digital integrator. A second oscilloscope displayed the force plate measurements.

Figure 13: Oscilloscope

Cameras. Two phase lock cameras were used to film simultaneously the jumping performance and the oscilloscopes. Both cameras ran at 100 frames per second.

Figure 14: Apparatus For Vertical Jump Experiment



Weight bar. This was a 20 kilogram weight lifting bar with additional weights available, allowing the total weight to reach 60 kilograms. A towel was wrapped around the center portion of the bar to cushion the back of the neck.

Weight rack. Between jumps the weight bar rested on a rack.

Chair. This was present to allow a sitting recovery between jumps.

Figure 15: Subject performing weighted vertical jump

Digitizing board. The films were projected on a Hewlett Packard 9864A Digitizer and from this the height of the vertical jumps and the impulses as displayed on the force plate oscilloscope were calculated.

Calculator. Information from the digitizing board was fed into the Hewlett Packard 9825A Calculator to interpret the displacements.

Shots. The regulation shot for the females was 4 kilograms and their overload shot was 12 pounds. For men, the regulation shot was 16 pounds. A heavier shot for the men was made by filling the center of a steel shot with lead. This increased the weight by 2 pounds. The 17 year old male used a 12 pound shot with the overload shot being 16 pounds.

Shot-put circle. The shot was put from a portable circle of 7 feet diameter with a curved stopboard fixed in the middle of the circumference of the front half of the circle.

Measuring tape. This was used to measure the shot-put performances.

Procedure

A. VERTICAL JUMP EXPERIMENT.

Instrument preparation. The Honeywell was adjusted to record both EMG and IEMG, while the force platform was attached to an oscilloscope. One camera was set up to film the pre- and post-jump trials and the other camera was set up to film the oscilloscopes and the digital IEMG reading on these trials.

Subject preparation. The subjects were briefed on the procedure (see Appendix C), given a consent form (Appendix D), and weighed. The 22 subjects came on three different days, allowing each subject to participate in the three different roles: Control "A" (no overload in warm-up, Control "B"

(no warm-up), and the Experimental Group (overload warm-up). The drawing of assignment cards (Appendix D) determined the sequence of participation in the three roles.

Procedure.

1. The left quadricep (rectus femoris) and iliac crest (ground electrode) were prepared for electrode application. The two electrodes on the rectus femoris were placed on the mid-portion of the muscle in a longitudinal plane about five centimeters apart from each other.(111)

2. The subject stood behind the force plate and relaxed quadricep.

3. The cameras were switched on.

4. The subject stepped to the center of the platform and immediately performed a maximal vertical jump. (This measurement constituted the pre-test.)

5. The cameras were switched off.

6. After this pre-test, the treatment varied as follows:

a. Control Group "A" subjects did 6 more jumps without the weight bar on the shoulders. A one-minute, sitting recovery was allowed between trials.

b. Control Group "B" subjects were given a 7 minute sitting recovery.

c. Experimental subjects performed 6 more jumps with a weight bar on the shoulders. The weight of this bar was 60 kilograms for the males and 40 kilograms for the females. As with Control "A", a 1-minute sitting recovery was allowed between jumps.

Note: Financial considerations limited the filming to the pre- and post-test jumps only.

7. All subjects were then post-tested with the procedure being a repeat of steps 2-5

B. SHOT-PUT EXPERIMENT

Subject Preparation. The subjects were briefed on the procedure (see Appendix E) and given a consent form. As was the case with the jump experiment, the subjects were randomly assigned to three different roles: Control "A", Control "B", and Experimental.

Procedure.

1. Subjects performed a pre-test, standing shot-put with the regulation weight shot (4 kilograms for women/12 pounds for the 17 year old male/16 pounds for men).

2. The following treatments were then implemented:

a. Control Group "A" subjects did 6 more standing shot-puts with the regulation shot allowing a 1-minute recovery between puts.

b. Control Group "B" subjects did no warm-up but rested for 7 minutes.

c. Experimental subjects did 6 more standing shot-puts with the overload shot (12 pounds for women/16 pounds for the 17 year old male/18 pounds for men). A 1-minute recovery between puts was allowed.

3. Subjects were then post-tested using the regulation shot.

The basic design for both experiments could be simplified as shown below:

Control "A": pre/6 no overload trials/post

Control "B": pre/7 minute rest/post

Experimental: pre/6 overload trials/post.

C. SUPPLEMENTARY SHOT-PUT EXPERIMENT

In this experiment, the subjects used an overload shot in the warm-up for an actual competition. Procedure in terms of number of warm-up puts,

and length of recovery between puts could not be controlled. Results were based on a comparison of the performance in this competition to shot-put performance in previous competitions (see Appendix F).

CHAPTER IV

RESULTS AND DISCUSSION

Results

TABLE I: VERTICAL JUMP (in centimeters)

In Table I the raw data for the vertical jump is presented. This measurement, in centimeters, is the peak height for the pre- and post-jumps for the three treatments. In each case the height was measured using a digitizing board with the digitizer following frame by frame the point where the subjects shirt tucked into their shorts.

	Name	Experimental		"A"		"B"	
		Pre	Post	Pre	Post	Pre	Post
♂							
1	D.Alt.	193.11	195.47	194.51	195.42	203.17	199.34
2	D.Ad.	175.71	174.57	189.46	180.81	182.47	178.92
3	K.W.	165.17	167.51	166.70	164.64	170.21	172.30
4	Ch.P.	173.04	171.89	164.65	171.60	175.45	173.26
5	P.D.	184.46	185.03	192.76	188.43	185.93	184.11
6	B.B.	196.69	200.34	195.45	198.88	196.42	195.38
7	Ch.D.	184.99	194.05	193.22	196.71	194.38	193.81
8	Jk.S.	211.52	208.98	210.29	204.79	199.10	206.67
9	I.K.	--	--	181.83	190.74	190.35	189.55
10	G.Rn.	--	--	192.32	201.15	195.44	200.11
Total		1484.69	1497.84	1881.19	1893.17	1892.92	1893.45
Average		185.59	187.23	188.12	189.32	189.29	189.35
♀							
11	Jo.A.	183.01	181.29	179.47	184.55	183.18	181.38
12	L.Ca.	153.24	155.78	148.79	154.04	146.16	149.48
13	L.Ge	170.52	174.65	173.88	176.17	177.52	178.92
14	L.Th.	181.63	182.04	177.54	182.90	175.93	178.66
15	J.Sh.	158.17	159.91	154.26	158.68	156.13	158.30
16	S.K.	148.91	151.32	158.50	152.83	151.49	153.57
17	G.G.	162.87	164.14	157.73	155.32	156.76	155.65
18	L.L.	188.10	188.40	185.94	188.70	184.45	185.15
19	M.Fr.	182.79	184.09	183.56	183.91	181.73	180.36
20	W.J.	151.40	151.31	159.43	157.83	156.58	159.22
Total		1680.64	1692.93	1679.10	1694.93	1669.93	1680.69
Average		168.06	169.29	167.91	169.49	166.99	168.07
Combined Total		3165.33	3190.77	3560.29	3588.10	3562.85	3574.14
Combined Average		175.85	177.27	178.01	179.41	178.14	178.71

TABLE II: PEAK FORCE (in Newtons)

Peak force was measured with a force plate for the vertical jumps. Table II shows the peak forces obtained for each of the subjects with the measurement expressed in Newtons.

	Name	Experimental Pre	Post	"A" Pre	Post	"B" Pre	Post
♂							
1	D.Alt.	2146.19	2042.08	1819.81	1855.62	2178.62	2399.68
2	D.Ad.	2121.98	1764.49	2528.33	2686.35	2126.55	2414.53
3	K.W.	1671.62	1897.46	1720.52	1642.12	2145.96	2187.63
4	Ch.P.	2083.74	1717.62	2362.58	2197.44	2199.43	2249.19
5	P.D.	2000.12	1856.07	2219.70	1987.47	1728.87	1446.11
6	B.B.	1662.33	1776.84	1623.84	1618.65	1743.95	1742.84
7	Ch.D.	2531.37	1978.58	2438.28	2605.42	2441.71	2163.94
8	Jk.S.	2408.73	2552.11	3267.03	2746.80	3698.52	3312.25
9	I.K.	--	--	2685.93	2708.55	2775.76	3339.99
10	G.Rn.	2627.91	--	2588.38	2026.77	2351.38	2188.89
♀							
11	Jo.A.	1942.51	2019.44	2142.48	2162.50	2282.27	1875.61
12	L.Ca.	1698.72	1698.72	1407.35	1549.11	1443.93	1338.18
13	L.Ge.	1415.82	1255.68	1524.28	1583.43	1761.53	1671.97
14	L.Th.	1397.64	1405.34	1758.76	1510.24	1614.68	1739.69
15	J.Sh.	1875.11	1947.70	1594.13	1863.90	1414.65	1415.62
16	S.K.	1999.63	2031.37	1748.69	1518.82	1902.37	1863.75
17	G.G.	1667.70	1813.32	1608.61	2002.77	1424.38	1558.19
18	L.L.	2342.86	2040.20	1926.73	2209.02	1991.43	1950.66
19	M.Fr.	1622.33	1776.84	1405.09	1453.37	1209.46	1373.84
20	W.J.	1696.55	1841.15	1491.12	1366.86	1587.80	1750.10

Although the pattern of force application can be gained by studying the force plate measurements (see Table III), an analysis of the total impulse may be invalid. First, due to financial restraints, a lengthy rolling of the film for each jump was not possible. The film was therefore often accelerating or decelerating as the subject took his/her jump. With a non-linear baseline, the area under the curve, or total impulse, would be innaccurate. Second, the oscilloscope reading of the force plate would drift slowly downwards after about 4 seconds when a subject was standing on the platform (see limitations, page 5).

TABLE III: PATTERN OF FORCE APPLICATION: NUMBER OF PEAKS (HIGHEST PEAK)

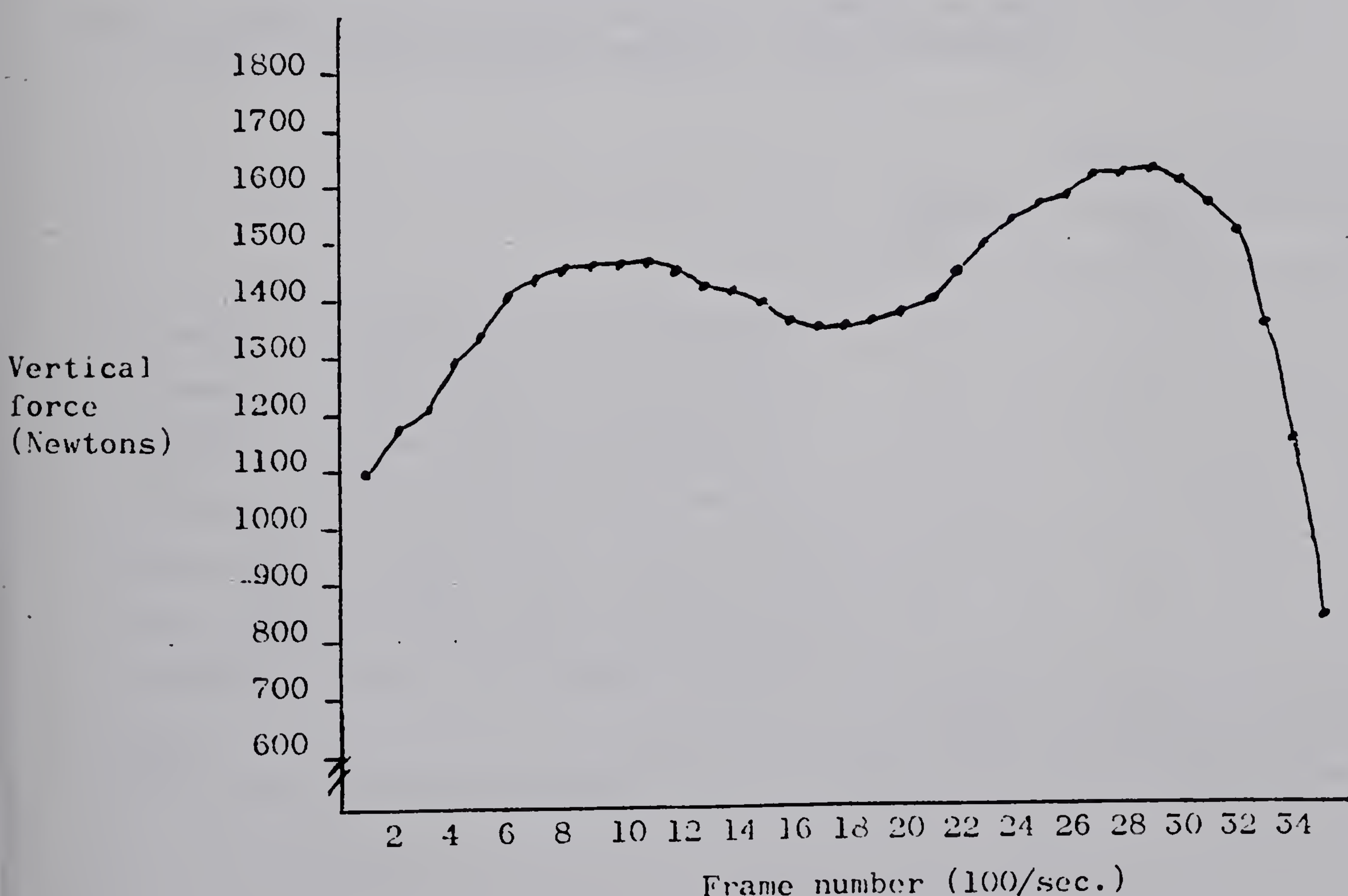
Name	Experimental Pre	Experimental Post	"A" Pre	"A" Post	"B" Pre	"B" Post
♂						
1 D.Alt.	3 (3)	3 (3)	2 (2)	2 (2)	2 (2)	2 (2)
2 D.Ad.	1 (1)	2 (2)	2 (2)	2 (2)	2 (2)	3 (1)
3 K.W.	2 (2)	2 (1)	3 (2)	2 (2)	3 (2)	2 (1)
4 Ch.P.	1 (1)	3 (3)	1 (1)	1 (1)	2 (2)	3 (3)
5 P.D.	2 (2)	3 (2)	1 (1)	2 (2)	2 (2)	4 (2)
6 B.B.	2 (2)	2 (2)	2 (2)	2 (2)	2 (2)	2 (2)
7 Ch.D.	2 (2)	2 (1)	2 (2)	2 (2)	2 (2)	2 (2)
8 Jk.S.	3 (3)	3 (1)	2 (2)	2 (1)	5 (1)	2 (1)
9 I.K.	--	--	3 (3)	2 (2)	3 (1)	3 (1)
10 G.Rn.	--	--	1 (1)	2 (2)	1 (1)	2 (2)
Total	16 (16)	20 (15)	19 (18)	19 (18)	24 (17)	25 (17)
Average	2 (2)	2.5(1.9)	1.9(1.8)	1.9(1.8)	2.4(1.7)	2.5(1.7)
♀						
11 Jo.A.	1 (1)	2 (2)	1 (1)	2 (2)	2 (1)	2 (2)
12 L.Ca.	2 (1)	2 (1)	2 (1)	2 (1)	2 (2)	2 (1)
13 L.Ge.	1 (1)	2 (2)	2 (1)	3 (1)	3 (2)	6 (3)
14 L.Th.	2 (2)	3 (2)	1 (1)	3 (1)	3 (1)	2 (1)
15 J.Sh.	2 (1)	3 (2)	1 (1)	2 (1)	3 (1)	3 (1)
16 S.K.	2 (1)	2 (1)	2 (2)	2 (2)	2 (1)	3 (1)
17 G.G.	5 (1)	5 (1)	5 (2)	2 (1)	1 (1)	1 (1)
18 L.L.	3 (1)	5 (1)	2 (1)	3 (1)	4 (1)	3 (1)
19 M.Fr.	2 (2)	2 (2)	3 (3)	3 (2)	2 (2)	3 (3)
20 W.J.	4 (1)	3 (2)	2 (2)	4 (2)	3 (3)	3 (3)
Total	24 (12)	26 (16)	21 (15)	26 (14)	25 (14)	28 (17)
Average	2.4(1.2)	2.6(1.6)	2.1(1.5)	2.6(1.4)	2.5(1.4)	2.8(1.7)
Combined Total	40 (28)	46 (33)	40 (33)	45 (32)	49 (31)	53 (34)
Combined Average	2.2 (1)	2.6(1.7)	2(1.65)	2.3(1.6)	2.5(1.6)	2.7(1.7)

Note: the number on the left in each column represents the number of peaks in each jump. The number in brackets signifies which of the peaks was the highest.

Within the limitations of this experiment, one might still expect a high correlation between the per cent change in the vertical jump performances and the per cent change in the peak force output or peak impulse. This was not the case (see Table IX). In other words, an improvement in a subject's height of jump does not necessarily mean that the peak force he imparted also improved. With a sustained force output, it is possible that the total impulse increases, but the peak force stays the same. The area under the curve, or total impulse, thus determines in a large part the success of the jump.

The most common pattern of force application showed two peaks with the largest peak being the second peak (see results Table III, page 45). Following is a typical pattern of force application.

TABLE IV: COMMON PATTERN OF FORCE PRODUCTION



For the subject represented in this graph, it was thought that the first peak represents hip extension with the second peak being a combination of knee and ankle extension as well as an upward arm swing adding to the vertical force. If all of the body parts contribute their peak force in quick succession, individual peaks are hidden. This is thought to be the best pattern. Males, on the average, had fewer peaks while jumping higher than did the females. Another sex difference was that the largest peak for the males was usually later in the force pattern than that of the females. Females would very often have the first peak being the largest peak.

As mentioned earlier, an overload warm-up may have the side effect of slowing the movement down with some loss of timing. This assumption is strengthened by the observation that it was very rare for subjects in the Experimental group to decrease the number of peaks.

TABLE V: RELATIONSHIP OF THE CHANGE IN NUMBER OF FORCE PRODUCTION PEAKS TO THE RESULTANT VERTICAL JUMP PERFORMANCE

	Number of Subjects						
	Exp.		"A"		"B"		Total
	M	F	M	F	M	F	
↑ number of peaks with ↑ performance	1	4	1	5	1	2	14
↑ number of peaks with ↓ performance	2	1	1	1	3	1	9
↓ number of peaks with ↑ performance			1		2	2	5
↓ number of peaks with ↓ performance			1	1			2
Same number of peaks with ↑ performance	4	4	4	2		3	17
Same number of peaks with ↓ performance	1		2	1	4	2	10
↓ number of peaks with same performance		1					1
Total	8	10	10	10	10	10	58

While only one subject decreased the number of peaks during the Experimental treatment, 3 subjects from Control "A" and 4 subjects from Control "B" decreased their number of peaks.

When the number of peaks stayed the same, there was usually an increase in performance for the Experimental and Control "A" treatment, but performance generally declined during the Control "B" treatment when the number of peaks remained the same. In addition to illustrating some superiority in the Experimental and Control "A" treatments, this relationship appears to reinforce the observation that if a consistently skilled subject uses the Experimental warm-up, performance is likely to be aided. With the above logic, it is assumed that a consistently skilled subject manages to keep the same pattern of force production from the pre- to the post-test while incorporating a beneficial overload effect.

An increase in peaks during the Experimental warm-up would be common to a less-skilled jumper as the increased number of peaks may be associated with a loss of coordination. One would therefore expect performance to decline if the number of peaks increased, but this was not usually the case. This was especially true for the Control "A" and Experimental treatments. An explanation for these results could be that in the pre-test, the subject neglected to make use of the potential force production from some body segment but then did add this force in the post-test. For example, arm swing may have been lacking in the pre-test but was made use of in the post-test. There appeared to be a sex difference in regards to the above relationship. Females were much more likely to increase the number of peaks while increasing performance than males. This possibly is due to a difference in skill level with the more highly skilled males less likely to make the mistake of neglecting to use a body segment in the pre-test.

TABLE VI: SHOT-PUT (in meters)

Table VI displays the raw data obtained from the shot-put experiment. The varying skill levels of the different subjects can be seen, although it should be noted that these were standing shot-put performances without the benefit of a glide. Generally, the higher skilled subjects showed greater consistency.

	Name	Experimental Pre	Experimental Post#1	Experimental Post#2	"A" Pre	"A" Post#1	"A" Post#2	"B" Pre	"B" Post
♂									
1	Ch.D.	10.15	10.78	--	9.80	9.58	--	9.11	9.96
2	T.D.	11.40	11.55	11.92	11.20	11.23	11.16	11.38	11.38
3	K.M.	10.85	11.14	11.93	10.61	11.44	--	10.80	11.61
4	G.Rn.	11.54	12.43	13.02	11.39	12.28	12.70	11.54	11.67
5	C.H.	11.41	11.43	11.32	11.57	11.88	11.53	11.25	11.14
♀									
6	S.K.	10.94	11.85	--	11.08	11.83	--	11.23	12.03
7	L.Th.	9.21	10.15	10.50	8.13	9.98	10.05	9.90	8.78
8	J.S.	10.25	10.53	--	10.25	10.44	--	9.90	10.39
9	M.Fr.	8.67	8.64	8.78	8.51	9.47	9.06	8.07	8.64
10	D.Fr.	8.81	8.30	--	8.78	8.67	7.93	8.39	8.19
Total		103.23	106.80	--	101.32	106.80	--	101.57	103.79
Average		10.32	10.68	--	10.13	10.68	--	10.16	10.38
*Total		52.23		55.54	50.80		54.50		
*Average		10.45		11.11	10.16		10.90		

*Note: Only those 5 subjects who did a second post-test for both the Experimental and the Control "A" treatments were included in these calculations

TABLE VII: SUPPLEMENTARY SHOT-PUT EXPERIMENT

In the following table (Table VII) the results of the supplementary shot-put experiment are shown. In this experiment 6 subjects used an overload warm-up in preparation for an actual competition. This experiment allowed comparison of the athletes' performance in this meet to their past performances. Two of the subjects recorded personal bests in this competition. Questionnaires filled out by the athletes in this experiment gave some subjective feedback concerning the overload warm-up. (See Appendix F)

Subject		Age	Sex	Recent Performances	Best Performance	Experimental Performance
1	S.K.	18	F	13.46/13.76/13.78	13.78	13.76
2	L.Th.	18	F	11.47/11.27/11.17	11.47	10.21
3	T.D.	19	M	12.00/12.00	12.59	11.91
4	G.Rn.	31	M	15.12/14.76/14.67	15.12	14.67
5	K.M.	23	M	12.57/13.02/12.95	13.02	13.03
6	C.D.	18	M	11.05/11.20	12.05	12.12

TABLES VIII & X

Tables VIII and X show the per cent change in vertical jump and shot-put performance respectively for the individual subjects. An examination of the individual results in either the shot-put or vertical jump experiments reveals the importance of gearing the warm-up to fit the individual. For some individuals, 10 or more warm-up trials would seem necessary to prepare them for competition, while others often get their best performance on the first trial. Although most of the athletes responded positively to the Experimental and Control "A" warm-ups, some found 8 trials to be fatiguing physically and/or mentally. For these athletes, the Control "B" treatment produced the greatest improvement. Fatigue through lactic acid build-up was believed not to be a factor, and this was confirmed by a blood lactate test taken during an Experimental treatment in the vertical jump. The blood lactate concentration in fact decreased.

TABLE IX

Nothing of significance can be gained through an examination of Table IX. As mentioned earlier, it is possible that the total impulse, instead of the peak force, determines the success of the jump.

TABLE VIII: VERTICAL JUMP RESULTS (per cent change)

Name	Experimental	Control "A"	Control "B"
♂			
1 D.Alt	1.22	0.47	- 1.88
2 D.Ad.	- 0.77	- 5.36	- 1.95
3 K.W.	1.41	- 1.24	1.23
4 Ch.P.	- 0.67	4.22	- 1.25
5 P.D.	0.37	- 2.24	- 1.15
6 B.B.	1.86	1.76	- 0.53
7 Ch.D.	4.90	1.81	- 0.29
8 Jk.S.	- 1.20	- 2.61	3.81
9 I.K.	--	4.90	- 0.42
10 G.Rn.	--	4.59	2.39
Total	7.12	6.30	- 0.04
Average	0.89	0.63	- 0.004
Standard Deviation	1.85	3.28	1.80
Sample Variance	3.40	10.78	3.25
Unbiased S.D.	1.97	3.46	1.90
Variance	3.89	11.98	3.61
♀			
11 Jo.A.	- 0.94	2.83	- 0.98
12 L.Ca	1.65	3.52	2.27
13 L.Ge.	2.42	1.32	0.79
14 L.Th.	0.22	3.02	1.50
15 J.Sh.	1.10	2.87	1.39
16 S.K.	1.62	- 3.58	1.38
17 G.G.	0.94	- 1.53	- 0.71
18 L.L.	0.16	1.46	0.38
19 M.Fr.	0.71	0.19	- 0.75
20 W.J.	- 0.06	- 1.00	1.68
Total	7.82	9.10	6.95
Average	0.78	0.91	0.70
Standard Deviation	0.93	2.23	1.10
Sample Variance	0.87	4.95	1.20
Unbiased S.D.	0.98	2.35	1.16
Variance	0.96	5.50	1.34
Combined Total	14.84	15.40	6.99
Average	0.83	0.77	0.35
Standard Deviation	1.41	2.81	1.53
Sample Variance	2.00	7.88	2.35
Unbiased S.D.	1.45	2.88	1.57
Variance	2.11	8.29	2.47

Correlations: Experimental and "A" = 0.196; Experimental and "B" = -0.075; "A" and "B" = 0.084

TABLE IX: PEAK FORCE RESULTS (per cent change)

Name	Experimental	Control "A"	Control "B"
♂			
1 D.Alt.	- 4.85	1.93	9.21
2 D.Ad.	-16.85	5.88	11.93
3 K.W.	10.87	- 4.56	1.90
4 Ch.P.	-17.57	- 6.99	2.21
5 P.D.	- 7.20	-10.46	-16.36
6 B.B.	6.44	- 0.003	- 0.06
7 Ch.D.	-21.84	6.85	-11.38
8 Jk.S.	5.62	-15.92	-10.44
9 I.K.	--	0.84	16.89
10 G.Rn.	--	-21.70	- 6.91
Total	-45.38	-44.13	- 3.01
Average	- 5.67	- 4.41	- 0.30
Standard Deviation	11.61	8.91	10.36
Sample Variance	134.85	79.46	107.39
Unbiased S.D.	12.41	9.40	10.92
Variance	154.11	88.28	119.32
♀			
11 Jo.A.	3.81	0.93	-17.82
12 L.Ca.	0.00	9.15	- 7.32
13 L.Ge.	-11.31	3.74	- 5.36
14 L.Th.	0.55	-14.13	7.19
15 J.Sh.	3.73	14.47	0.07
16 S.K.	1.56	-13.15	- 2.03
17 G.A.	8.03	19.68	8.59
18 L.L.	-12.92	12.78	- 2.05
19 M.Fr.	8.70	3.32	11.97
20 W.S.	7.85	- 8.33	9.27
Total	10.00	28.46	2.51
Average	1.00	2.85	0.25
Standard Deviation	7.20	11.09	8.73
Unbiased S.D.	7.59	11.69	9.20
Sample Variance	51.78	123.06	76.23
Variance	57.53	136.73	84.70
Combined Total	-35.38	-15.67	- 0.50
Average	- 1.97	- 0.78	- 0.025
Standard Deviation	9.98	10.70	9.59
Sample Variance	99.69	114.45	91.88
Unbiased S.D.	10.27	10.98	9.83
Variance	105.56	120.48	96.72

Correlations: Experimental Force Plate to Experimental Vertical Jump = -0.212
"A" Force Plate to "A" Vertical Jump = 0.038
"B" Force Plate to "B" Vertical Jump = -0.264

TABLE X: SHOT-PUT RESULTS (per cent change)

Name	Experimental (Post #1)	Experimental (Post #2)	"A" (Post #1)	"A" (Post #2)	"B"
1 C.D.	6.21		- 2.24		9.33
2 T.D.	1.32	4.56	0.27	- 0.36	0.00
3 K.M.	2.67	9.95	7.82	--	7.50
4 G.Rn.	7.71	12.82	7.81	11.50	1.13
5 C.H.	0.17	- 0.79	2.68	- 0.35	0.98
Total	18.08		16.34		17.93
Average	3.62		3.27		3.39
6 S.K.	8.32		6.77		7.12
7 L.Th.	10.21	14.01	22.75	23.62	-11.31
8 J.S.	2.73		1.85		4.95
9 M.Fr.	- 0.35	1.27	11.28	6.46	7.06
10 D.Fr.	- 5.79		- 1.25	- 9.68	2.38
Total	15.12		41.40		10.20
Average	3.02		8.28		2.04
Combined Average	3.32	* 6.53	5.78	* 8.17	2.72

*Note: Only those 5 subjects who did a second post test for both the Experimental and the Control "A" treatments were included in this calculation.

TABLE XI: SIGNIFICANCE OF THE DIFFERENCE (t-test) Pre to post summary.
$H_o:M_1 - M_2$ $\alpha = .05$, 1 tailed

A t-test was used to find the significance of the difference for the various categories of warm-up treatments. Those that have been found significant at the .05 level have been marked with an *. There is a weakness in using a large number of t-tests in that 5 per cent of the time, or 1 t-test out of 20, (when testing at the .05 level), there is likely to be a t-test which appears significant but in reality it isn't. Nevertheless, the Experimental treatment does show some advantage over the controls in regards to this statistic. It should be noted that when a second post test was added in the shot-put experiment a further significant improvement was found. The implications of this will be discussed later.

A. VERTICAL JUMP

	Obtained t	N - 1	Necessary t
I. Experimental			
Females	2.39	9	1.83*
Males	1.27	7	1.90
Combined	2.27	17	1.74*
II. Control "A"			
Females	1.32	9	1.83
Males	0.61	9	1.83
Combined	1.24	19	1.73
III. Control "B"			
Females	1.81	9	1.83
Males	0.05	9	1.83
Combined	1.05	19	1.74
B. PLATE FORCE			
I. Experimental			
Females	0.37	9	1.83
Males	-1.31	7	1.90
Combined	-0.92	17	1.74
II. Control "A"			
Females	0.89	9	1.83
Males	-1.46	9	1.83
Combined	-0.51	19	1.73
III. Control "B"			
Females	-0.17	9	1.83
Males	-0.92	9	1.83
Combined	-0.94	19	1.73
C. SHOT-PUT			
I. Experimental (1st post)			
Females	1.14	4	2.13
Males	2.48	4	2.13*
Combined	2.35	9	1.83*
II. Experimental (2nd post)			
Females	1.19	1	6.31
Males	2.19	3	2.35
Combined	2.77	5	2.02*
III. Control "A" (1st post)			
Females	2.14	4	2.13*
Males	1.69	4	2.13
Combined	2.75	9	1.83*
IV. Control "A" (2nd post)			
Females	0.68	2	2.92
Males	0.91	2	2.92
Combined	1.15	5	2.02
V. Control "B"			
Females	0.31	4	2.13
Males	1.64	4	2.13
Combined	1.14	9	1.83
D. SHOT-PUT (1st to 2nd post)			
I. Experimental	2.73	5	2.02*
II. Control "A"	-1.08	5	2.02

TABLE XII: SIGNIFICANCE OF THE DIFFERENCE (t-test) Experimental to Control "A" to Control "B" summary. $H_o M_1 = M_2 = M_3$. $\alpha = .05$, 1 tailed

The final statistical analysis to be performed was a t-test to determine the significance of the difference between the different treatments. This is shown in Table XII. No significant differences could be found.

	Obtained t	N - 1	Necessary t
I. Vertical jump			
Exp. to "A"	0.16	17	1.74
Exp. to "B"	-0.85	17	1.74
"A" to "B"	-0.65	19	1.73
II. Shot-put (1st post)			
Exp. to "A"	1.09	9	1.83
Exp. to "B"	-0.55	9	1.83
"A" to "B"	-0.98	9	1.83
III. Shot-put (2nd post)			
Exp. to "A"	0.37	4	2.13

Discussion

It would be justified to point to the lack of significant difference between the three treatment groups for both the vertical jump and shot-put experiments (see Table XI) and conclude that an overload warm-up is no better or worse than a non-overload warm-up or no warm-up at all. A closer look at the data, though, does reveal some promise that an overload warm-up could aid performance if properly applied.

The proper application of overload implies that there is fairly close adherence to the principle of specificity, allowance for a timing regaining period at the end of the overload trials, and that the overload is adapted

individually. As well, the performers should be consistent in their skill so that the correct neuromuscular pattern is more or less automatic.

Specificity must be sacrificed to some extent when using an overload warm-up. The greater the overload, the less the specificity. The vertical jump experiment made use of quite a taxing overload. The 40 to 60 kilogram bar was approximately 2/3 to 3/4 the subject's body weight. This weight, especially when held as a weight bar on the shoulders, alters the ideal movement pattern for the vertical jump. The overload jumps were performed slowly and cautiously with the arms holding the bar instead of adding thrust to the jump. Despite this obvious sacrifice of technique, the female, and the male and female combined scores were significantly better (0.05 level) after an overload warm-up. The same could not be said after either of the control treatments (see Table XI).

The shot-put experiments had a relatively smaller overload, and, to the casual observer, no change in technique could be noted. The extra weight did slow the movement down though, but this may be an advantage instead of a disadvantage. One subject in the supplementary experiment explained: "A heavier shot is a good way to warm-up for me because it slows you down a bit: thus, you can feel your position better and when you get back to your normal shot you have more spring." (Appendix F) Another subject thought the heavier shot improved his ability to finish the throw. In the explosive action of the shot-put, wrist and finger flexion are the last to contribute to force output. The slightly slower put apparently allowed a greater force contribution by the smaller muscles at the end of the put.

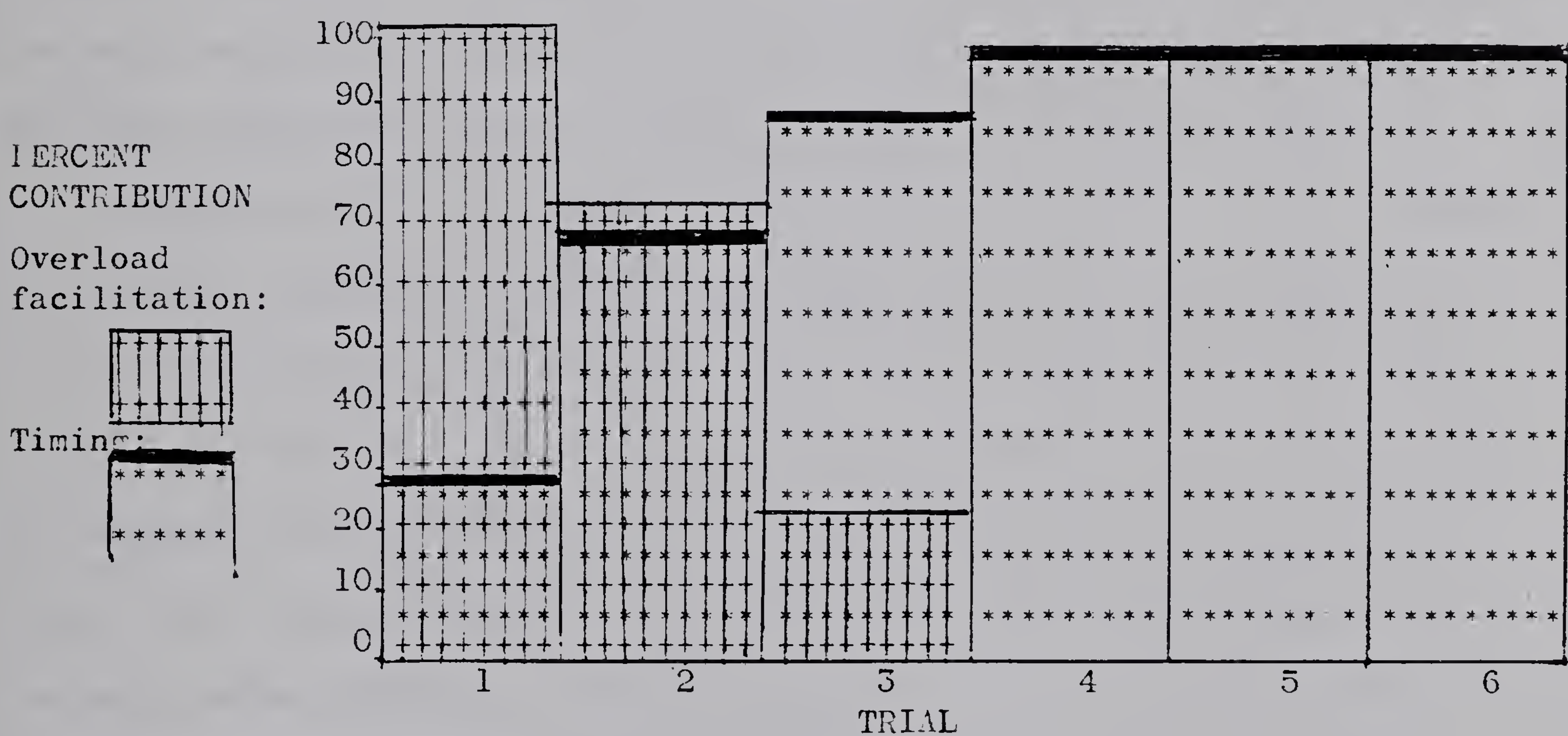
These experiments did not have the means to tell which factors contributed the most to the obtained results, but it appears feasible that a slowing

down of the movement could aid in rehearsing the proper action. In addition, as hypothesized earlier, the overload could induce greater motor recruitment. These factors appeared to balance the loss of specificity in the shot-put experiment as the improvement to both the Experimental and Control "A" treatment groups were significant. Control "B", which did no warm-up, did not achieve a significant improvement in shot-put performance (see Table XI).

A further significant increase in shot-put performance was noted with the Experimental group when a second post-test was added. This pattern did not hold with the Control "A" group, and their performance, in fact, declined on the second post-test (see Table XI). Van Huss (110) had noticed a similar effect when he studied an overload warm-up applied to the baseball throw. In his experiment, the majority of the subjects improved their velocity of throwing, but the accuracy of the first few throws following overload warm-up was impaired. While the added resistance may aid coordination as it induces a slow-motion rehearsal, the timing must be readjusted to a faster speed after the extra resistance is removed. This readjustment apparently involves one, possibly more, trials. A weakness of this study was that the vertical jump experiment used just one post-test, and the shot-put experiment had only one or two post-tests. In the supplementary shot-put experiment, there were essentially 6 post-test trials, as 6 puts are allowed in the competition. Three of the competitors had their best puts on the second trial, but the other 3 competitors achieved their best put on the fourth, fifth or sixth trial. The overload effect is temporary, and, at some point after an overload warm-up, one would expect the overload effect (greater recruitment and/or increased rate of motor firing) to wear off, but, with the present knowledge, it is difficult to put a quantitative

figure on the number of trials necessary. As the overload effect is wearing off, better coordination is possibly being regained. Ignoring other performance factors, the trial at which coordination intersects the overload effect may be the optimal point for a good put. Judging by the varying trials at which the shot-putters achieved their best put in competition, one can see that the optimal point is individual in nature. The following graph depicts this intersection with the best combination of the two factors occurring in trial #2.

TABLE XIII: THEORETICAL MODEL OF THE RELATIVE CONTRIBUTION OF OVERLOAD FACILITATION & TIMING TO SHOT-PUT PERFORMANCE



The number of trials is probably a greater determinant than is time in effecting the decline of the overload facilitation. In the review of literature, it was noted that a persisting increase in discharge from muscle spindle fibers at a maintained muscle length and in response to stretch appears after a muscle has undergone contraction. This post-excitatory facilitation was found to persist for many minutes but disappear following

a brief stretch of the muscle. With each post-trial, the overload muscles would receive some degree of stretch and the facilitatory effect would probably quickly decline in a step-like fashion with each trial as illustrated in the preceding diagram.

In the pilot study for this research, it was found that the older, better skilled subjects had the greatest improvement in response to the overload warm-up. This trend continued in the present study. The subjects who showed the greatest improvement in the vertical jump, Experimental treatment were generally those subjects most familiar with performing a vertical jump with a weight bar on the shoulders. In the shot-put experiment, the more experienced, highly-skilled shot-putters achieved their largest per cent improvement after the overload warm-up (see Tables VI and X).

Unfortunately, the integrated EMG could not be read. If the figures were clear, a quantitative figure that takes into account the number of motor units recovered, their firing rate, and their amplitude, could be added to the results. If, as hypothesized, more motor units are recruited in response to the overload and this greater recruitment persists to a later trial, the difference between the skilled consistent performer and the more novice competitor could be explained in terms of two opposing mechanisms which determine the amount of motor recruitment in a muscle:

1. more motor units are being recruited to increase the force of contraction, or

2. more motor units are being recruited but because of a lack of coordination they are not contributing their input in the proper sequence. Practice would tend to limit the excitation centers in the cerebral cortex and only those muscles needed in the movement would be called into play.

The skilled performer then incorporates the increased recruitment into his "automatic" efficient pattern of movement, and, because the proper coordination and timing is not sacrificed to a very large extent, it can be quickly regained after one or two trials following the overload. An "automatic" efficient pattern of movement is more vulnerable with the unskilled performer, with the overload simply adding to the vulnerability.

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

Conclusion

The use of the overload warm-up to enhance performance in explosive power events such as the vertical jump or shot-put does show promise if the overload is properly applied. Although a statistically significant difference in improvement between the two Controls and the Experimental treatment could not be found, some trends in the results appear to favor the Experimental treatment. There was a significant improvement in both the vertical jump and shot-put performances when the overload warm-up was applied, while the Control "A" warm-up allowed a significant improvement in shot-put performance only. The Control "B" warm-up gave no significant improvement for either the shot-put or vertical jump experiments.

The proper application of overload was determined to involve:

- adherence to the principle of specificity in that technique should not be greatly altered when overload is applied.

- allowance for a timing regaining period at the end of the overload trials. This was brought to light in the shot-put experiment when a second post-test produced a further significant improvement over the first post-test.

- adaptation of the overload to the individual as the different subjects varied in their response to the treatments.

The review of literature presented a physiological rationale for increased power through an overload warm-up. Power could possibly be improved through increased rate and/or amount of motor unit recruitment. Overload may enhance recruitment through a proprioceptive neuromuscular facilitation mechanism or improved sympathetic tone.

Recommendations (for future study)

- the subjects selected should be consistent in their skill level.
- a large number of subjects should be selected as the differences in improvement between various warm-ups may be subtle.
- more than one post-test should be applied.
- an integrated EMG reading from proven instrumentation and procedure would be valuable in determining the underlying physiological mechanisms.
- different overload procedures should be applied, for example: gradually increased resistance, more repetitions, longer or shorter recovery.

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APPENDIX A

ELECTROMYOGRAPHY

ELECTROMYOGRAPHY

Physical Education 547

Submitted to Dr. Quinney

By Ian Newhouse

November 26, 1980

"Electromyography is the study of muscular function by recording the electrical impulses inherent within the muscle tissue". (2)

Introduction

Galvani at the end of the eighteenth century revealed that skeletal muscles will contract when stimulated and conversely, that muscles will produce a detectable current or voltage when they contract from any cause. (3) It was not until the twentieth century (1940s), though, that neurophysiologists developed the technique of electromyography (EMG) to study the electrical potentials produced by muscles. Anatomists, kinesiologists, and orthopedic surgeons would now not have to guess what the muscle "ought to do" (3) but could analyse what a muscle actually does do at any moment during various movements and postures. With increasing sophistication of the apparatus and specialized recording systems, researchers in physical education have learned much about the exact timing and interrelationships of muscle group contractions during movements. These objective revelations would be impossible by any other means.

Physiological Basis

The basis of electromyography is the motor unit. The nerve cell body, the long axon of the motor nerve, its terminal branches and all of the muscle fibers supplied by these branches constitute the motor unit. The number of muscle fibers per motor unit depends on the degree of fine adjustment needed by the muscle. While the muscles controlling eye movement may have less than 10 fibers/unit, the quadriceps may have more than 100 fibers/unit. A strong contraction of skeletal muscle requires the contraction of many such motor units. An asynchronous volley of impulses, with each motor unit twitching up to 50/sec. results in a continuous shower of twitches allowing a smooth

pull by the muscle. The cumulative result of a series of electrical impulses is called summation. With a very high frequency of impulses the motor unit twitches can summate to form a tetanus. Each twitch elicits a minute electrical potential with a duration of 1-4msec. Because all of the fibers of a motor unit do not contract at exactly the same time the electrical potential of the unit lasts 5-12 msec. This electrical discharge can be picked up by electrodes and measured in terms of frequency, duration and amplitude with the deflections displayed on a trace recording of an EMG.

Apparatus

ELECTRODES

There are a wide variety of electrodes used for EMG but these could be divided into two main types; surface or skin electrodes and inserted (needle or wire) electrodes. Both must be brought close enough to the muscle(s) being studied to pick up its electrical charges.

Surface electrodes have the advantage of convenience; they are easy to use and give little discomfort to the subject. Three surface electrodes can be purchased through Hewlett Packard Medical Suppliers. They are approximately 2.5 cm. in diameter and constructed from a silver metal disc set into a plastic insulating cup. A circular adhesive strip secures the electrodes to the skin. A saline electrode jelly improves the electrical contact. It is essential that electrical resistance be kept to a minimum and to this end the dead surface skin and protective oils should be rubbed off before an electrode is applied. The optimum distance between the electrodes is six to ten cm. A third electrode acts as a ground and is attached to a bony prominence away from the muscle being studied. The disadvantages of surface electrodes are that they can only be used with surface muscles and they do not offer precision.

The disadvantages of the surface electrodes are the advantages of inserted electrodes such as the needle or wire electrodes. Basmajian (3) prefers the fine-wire, bi-polar electrodes over both surface and needle electrodes. Reasons for this are:

"1. extremely fine (and therefore painless)
2. easily implanted and withdrawn
3. as broad in their pick up from a specific muscle as are the best surface electrodes, and yet,
4. they give beautiful, sharp spikes similar to those from needle electrodes." (3)

There are various types of needle and wire electrodes but all, of course, involve insertion of the electrode into the muscle.

ELECTROMYOGRAPHS

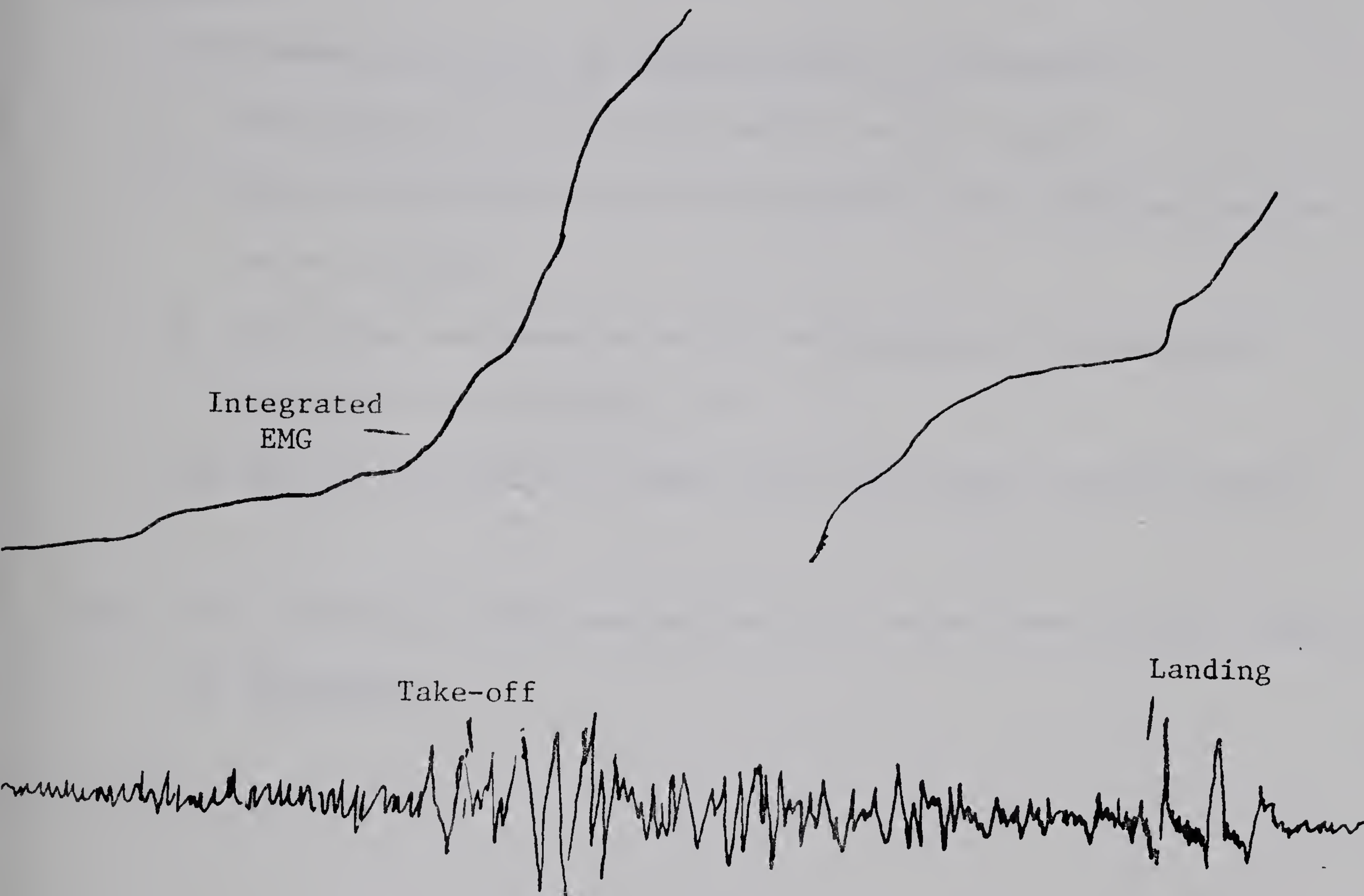
There are a wide range of electromyographs; some are home made, some are converted from EEG or ECG equipment and some are custom made. The physical education faculty at the University of Alberta has a Honeywell Electronic Medical System. This particular machine consists of seven visual recording channels with each channel containing a transducer, electronic conditioning equipment and a recording or readout device. Basmajian (3) describes an electromyograph as basically "a high gain ampliphier with a preference or selectivity for frequencies in the range from about 10 to several thousand Hz (cycles per second)." It may be practical to have an ampliphier that rejects frequencies below 20 Hz and above 200 Hz when using surface electrodes as this would limit "ampliphier noise", general non-muscular "tissue noise" and any other outside electrical interference which upsets the EMG tracing. At the same time there would be no significant loss of the motor unit potentials. This Honeywell machine has an EMG channel with an Accudata 135

biomedical ampliphier and a galvanometer in a model 8011 oscilloscope. This oscilloscope can display 3 channels simultaneously with sweep speeds of 10, 15, 25 and 100 mm/sec. The sensitivity, waveform amplitude and vertical positioning can be controlled. It runs on a single ended DC voltage and low frequency AC voltage inputs.

An Accudata 136 physiological integrator can be equipped to the EMG channel. An integrator will average or summate the complex EMG recording to give a more simplified recording. They take the variables of amplitude, frequency, and spike shape and give an arbitrary quantitative figure. The shortcomings of an integrated EMG read out are that one cannot discriminate between artifacts (outside electrical interference) and unit potentials. Another problem is that integrated potentials from one channel cannot be compared to those from another.

RECORDING DEVICES

Both the EMG output and the integrated EMG can be displayed on a paper reading from an oscillograph. The model 1912 Visicorder Oscillograph uses a high intensity, ultra violet light source to record on ultra violet light sensitive paper. The printout papers are developed with exposure to normal light. This type of printout is greatly superior, though much more expensive, to the more common mechanical ink writers which are not responsive enough to do accurate EMG work. Paper speed on this machine can vary from .25 cm/sec. to 400 cm/sec. On the next page is an EMG printout on light sensitive paper. Two electrodes were placed on the rectus femorus with a ground electrode on the iliac crest. The subject was a 16 year old girl and she performed the vertical jump.



EMG - Nancy Newhouse, Age 16, Vertical Jump
- Rectus Femoris, Nov. 7, 1980.

The bottom line shows an EMG muscle action potential, while the middle line (although faint) is an integrated EMG. The top line is nothing in this instance but could show a number of other physiological functions if that channel were operating. The second burst of activity represents an eccentric contraction as the subject absorbs on landing. A more detailed study may

have filmed the movement to better coordinate the action with the printout.

Conclusion

Electromyography gives us 3 major types of information:

1. which muscles or parts of a muscle are activated;
2. the chronological order of involvement of the different muscles in an activity;
3. the degree and duration of the contraction of the different muscles in each movement. (1)

This type of evaluation is impossible using other research methods.

Note: for a listing of EMG manufacturers the reader should consult page 440 of Basmajian.

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2. Bauer, Tony. Electromyographic Fatigue Curves. Masters Thesis. Edmonton: University of Alberta, 1976.

3. Basmajian. Muscles Alive. Baltimore, Maryland: Williams and Wilkins Co., 1974.

APPENDIX B

FORCE PLATFORM

Pages 81-88 are copyrighted material regarding the Stoelting Force Sensitive Platform (Cat. No. 19570).

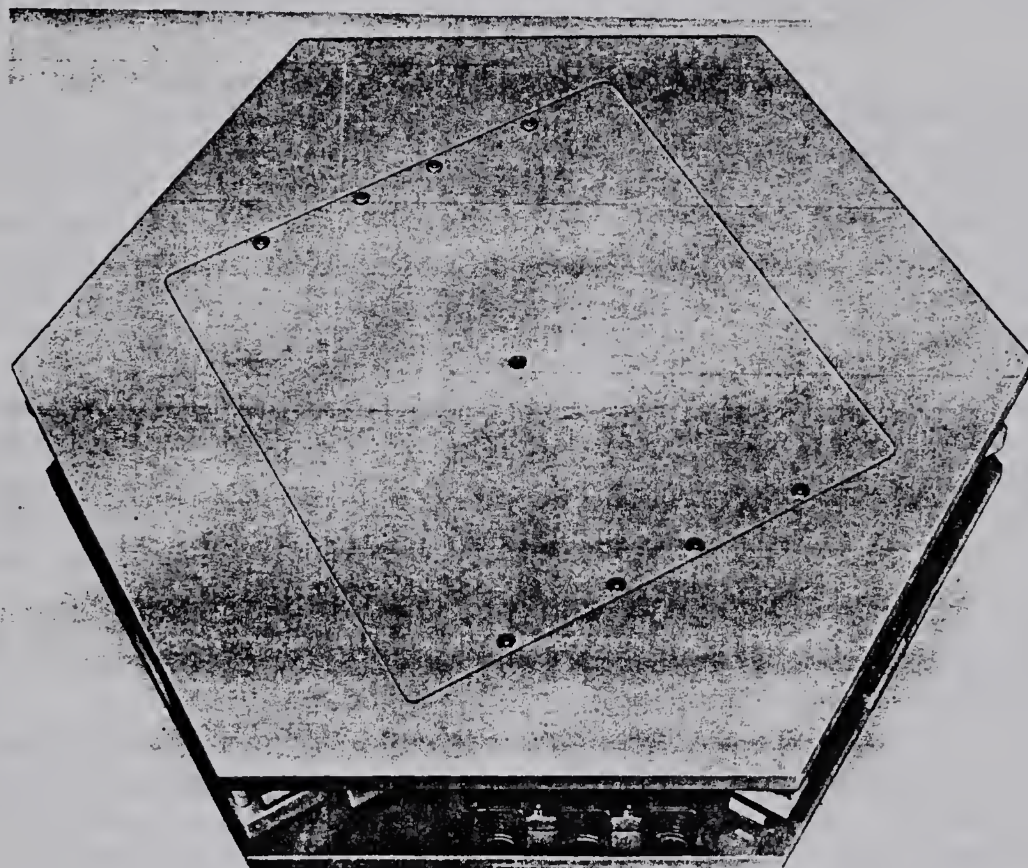
This material may be obtained from:

Stoelting Company
1350 S. Kostner Avenue
Chicago, Illinois

Stoelting's

CAT. NO. 19570

FORCE SENSITIVE PLATFORM
(MODIFIED LAURU)



For the study of forces exerted while executing bodily movements. The modified design uses "Linear Variable Differential Transformers" (LVDT) instead of quartz crystals. The platform is hexagonal in shape approximately 25" x 22" x 5" and weighs less than 100 pounds. The design maintains the geometric properties of the equilateral triangular placement of the cantilever beams. The LVDT's require 400 cps, 6 volts for excitation; the recorder should have a sensitivity of 1 cm pen movement for 1 mv change and have 3 recording channels.

The platform is capable of measuring the forces exerted by a subject while performing various types of muscular work and is sensitive enough to record the heart beat of a motionless subject.

The instrument is suitable for laboratory experiments, study of work methods and measurements, human engineering and job design. Among the type of experiments that might be performed with this equipment are the following:

(1) detection of the differences in work methods;

(2) indication of optimum arrangement of controls and displays in man-machine systems;

(3) classification of jobs by physiological effort.

(4) demonstration of the effects of individual differences on job performance.

Other areas of application may be in the study of diagnostic and therapeutic techniques with handicapped individuals. Animal activities could also be monitored with the use of this device. The device is reasonably linear in all axes with frequencies as high as 250 cps. The natural frequency is beyond 400 cps and there is no noticeable interaction between axes. ?

The platform is shipped completely assembled and wired and should be calibrated when installed. Instructions are furnished with unit. A

STOELTING COMPANY - 1350 S. KOSTNER AVE - CHICAGO, ILLINOIS 60623

A PORTABLE FORCE - PLATFORM
FOR MEASURING BODILY - MOVEMENTS

The study of the forces exerted while executing a bodily movement has long been of interest to physiologists, psychologists, and industrial engineers. Development of an instrument for measuring bodily forces dates back to the nineteenth century when physiologists constructed myographs for quantifying the extent, force, and duration of muscular contractions. Wendt (1938) and Davis (1942) reviewed various techniques of recording the forces exerted by a specific bodily member; however, conclusions concerning the total amount of bodily force exerted had to be based on inference.

Lauru (1957) developed a force-sensitive instrument utilizing piezoelectric quartz crystals which have the somewhat unique property of emitting a small electrical voltage proportionate to the amount of externally applied pressure. Five such crystals were incorporated into a triangular platform consisting of two sections. The top level rested on three of the crystals, one placed at each corner, in order to measure vertical forces. The remaining two crystals were mounted on the outer edges of the platform. One, resting against a corner, registered forward and backward forces; and the other one, resting against a side, registered transversal forces. After proper amplification, the electrical impulses were recorded by means of an oscillograph. The result was a graphic record of the total amount of vertical, frontal, and transversal forces exerted during a bodily movement.

Greene and Morris (1959) designed a force-platform consisting of a top plate in the shape of an equilateral triangle supported by a frame which, in turn, was supported at the corners by steel ball bearings resting on cantilever beams. Horizontal movements were restricted by two other sets of beams, also acting through steel balls. A steel subframe supported the beams. Because deflections in a cantilever beam are directly proportionate to the applied forces, the beams could be used to measure the forces generated by a bodily-movement. The beam deflections were transformed into electrical signals by means of Linear Variable Differential Transformers (LVDT) and recorded with a Universal Brush Analyzer. The triangular design and the arrangement of the beam could resolve any externally applied force into its three orthogonal components.

The force-platform is a re-designed version of the original model constructed by Greene. The new design maintains the geometric properties of the equilateral triangular placement of cantilever beams and the utilization of LVDT sensing units but possesses the added features of being compact, portable, and relatively inexpensive to reproduce. The device weighs less than 100 pounds, with over-all dimensions of 25" x 22" x 5". The force-platform can be used in conjunction with any standard three channel recording instrument that has a 400 cps, 6 volt source for gage excitation and is capable of one centimeter of pen deflection per one millivolt change in excitation.

The re-designed force-platform is capable of measuring the forces exerted by a subject while performing various types of muscular work and is sensitive enough to record the heart beat of a motionless subject.

The instrument is suitable for laboratory demonstrations and experiments for undergraduate courses in work methods and measurement, human engineering, and job design. Among the types of experiments that might be performed with this equipment are the following: (1) detection of differences in work methods; (2) indication of the optimum arrangement of controls and displays in man-machine systems; (3) classification of jobs by physiological costs; and (4) demonstration of the effects of individual differences on job performance.

In addition to the above uses, the instrument may be advantageously utilized in fields far removed from Industrial Engineering. For example, diagnostic and therapeutic techniques with handicapped individuals may be investigated through study of bodily forces. Similarly, the platform could be used to investigate the development of motor and coordinational skills in children. The apparatus could be used in comparative psychology in order to measure the reaction of a rodent to some noxious stimulus. Undoubtedly, the research oriented individual can think of many other possible applications of this instrument.

STRUCTURAL CHARACTERISTICS

Mechanically, the force-platform consists of a 3/4 inch thick hexagonal aluminum top-plate and truss section suspended vertically by six horizontal cantilever beams and restricted horizontally by six vertical cantilever beams. In turn, the twelve beams plus three sensing units are supported by an aluminum base plate.

Forces V1, V2, and V3 in the Schematic Diagram represent the weight of the suspended portion of the platform plus any other downward vertical force that might be exerted on the instrument. These three forces are exerted at three points which form the vertices of an equilateral triangle. Forces V4, V5, and V6 represent the upward vertical forces that might be exerted on the platform during transportation or large displacements. The three upward forces form the vertices of a second equilateral triangle superimposed on the triangle formed by the downward forces. The common intersection of the perpendicular bisectors of the sides of the triangle formed by the upward forces is on the same vertical axis as the intersections of the perpendicular bisectors of the sides of the triangle formed by the downward forces. This arrangement not only restricts the platform in both vertical directions, but, a constant force exerted in either direction anywhere on the platform will result in the same amount of deflection at the center point of the hexagonal top-plate.

Forces F1, F2, F3, and F4 represent the frontal forces and forces L1 and L2 represent the lateral forces exerted on the platform. Horizontal movement of the suspended portion of the platform is restricted by the two sets of vertical beams.

The restrictive forces in the vertical and horizontal directions are exerted at point contacts consisting of steel balls pushing against flat tool-steel surfaces attached to the cantilever beams. Therefore, only forces perpendicular to the restricting beams will cause beam deflection.

DEFLECTION SENSING

Deflection in the three orthogonal directions is detected by shielded Linear Variable Differential Transformers. These devices consist of three adjacent coils wound on the same insulated spool. A magnetic core is initially located in the center of the middle coil. Linear deflection of the core along the axis of the coils causes increased coupling of the center coil with one of the end coils; while linear deflection in the opposite direction causes increased coupling of the other end coil. This voltage differential in the end coils is used as an input signal to a recorder.

The vertical deflection sensing unit S1 is placed at the common center of the two equilateral triangles. An adjustable set screw through the center brace of the truss section is used as the sensing face as shown. The frontal sensing unit S2 is placed along the frontal axis passing through the center of the platform. A vertical plate perpendicular to the frontal axis is used as the sensing face. Only deflections parallel to the frontal axis will displace the core. The lateral sensing unit S3 is placed along the transversal axis which passes through the center of the platform. A sensing face similar to the frontal one is used so that only deflections parallel to the lateral axis will displace the core in the lateral sensing unit.

CALIBRATION TECHNIQUE

The diagram shows the calibration set-up with the force-platform bolted to the center of a three foot square aluminum base. A movable center-post is clamped to the outer edge of the base plate. Horizontal static forces are exerted against a cross-frame by means of a threaded shaft acting through a calibrated spring scale. The cross-frame is bolted to the top of the platform. Vertical static forces are applied to the top of the platform by means of dead weights.

Calibration of dynamic forces can be achieved by means of a variable speed motor rotating an off-center circular cam of known mass. The motor can be moved along the cross-frame in order to record frontal or transversal forces.

Models of the force-platform were subjected to an extensive series of tests with static and dynamic weights. The instrument exhibited reasonable linear force response curves for all axes with frequencies as high as 250 cpm. The natural frequency of the device was beyond 400 cpm, well above the requirements for most experiments using human and infrahuman subjects. There was no evidence of interaction between axes. As previously stated, the sensitivity of the device was sufficient to record the heart beat of a motionless human subject.

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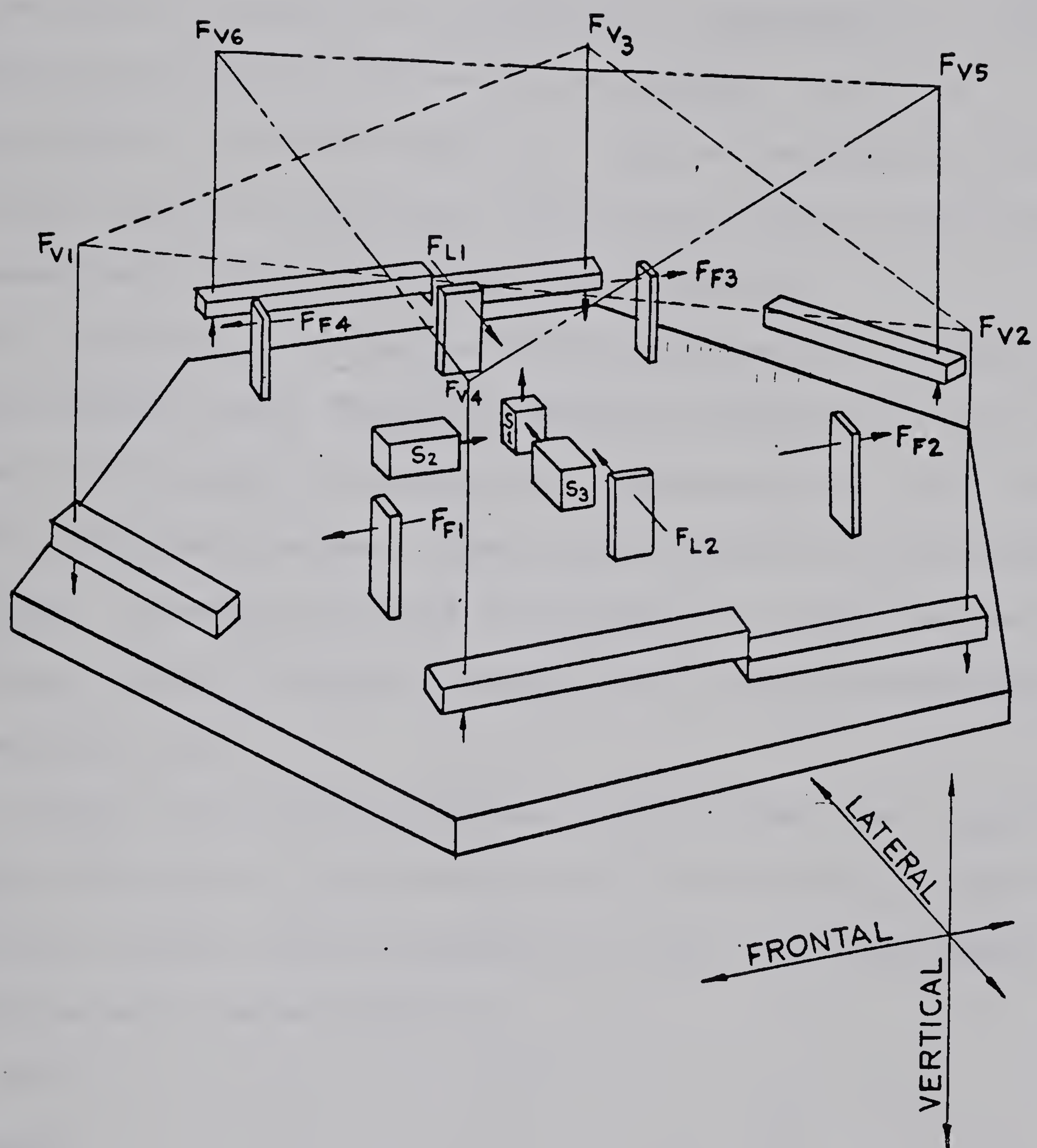


SCHEMATIC DIAGRAM OF THE FORCE PLATFORM

19570 - LARU FORCE PLATFORM

SPECFICATION

1.0 General

1.1 The Force Platform is essentially a transducer to convert forces applied to its sensitive surface, into proportional electrical signals. Due to the design of the platform, applied forces are resolved into three orthagonal components, frontal, lateral and vertical.

1.2 The platform is suspended and restricted by a system of cantilever beams that provide good isolation between axes and low mechanical compliance. Movements are translated to LVDT cores, whose stators are anchored to the reference plane. Movement between a core and its stator produce an output signal linearly proportional to displacement and the applied force.

1.3 A three channel exciter/demodulator system (not supplied) must be used in conjunction with the platform. The demodulated outputs can be recorded on most recording media.

2.0 Transducer Characteristics

2.1 Input

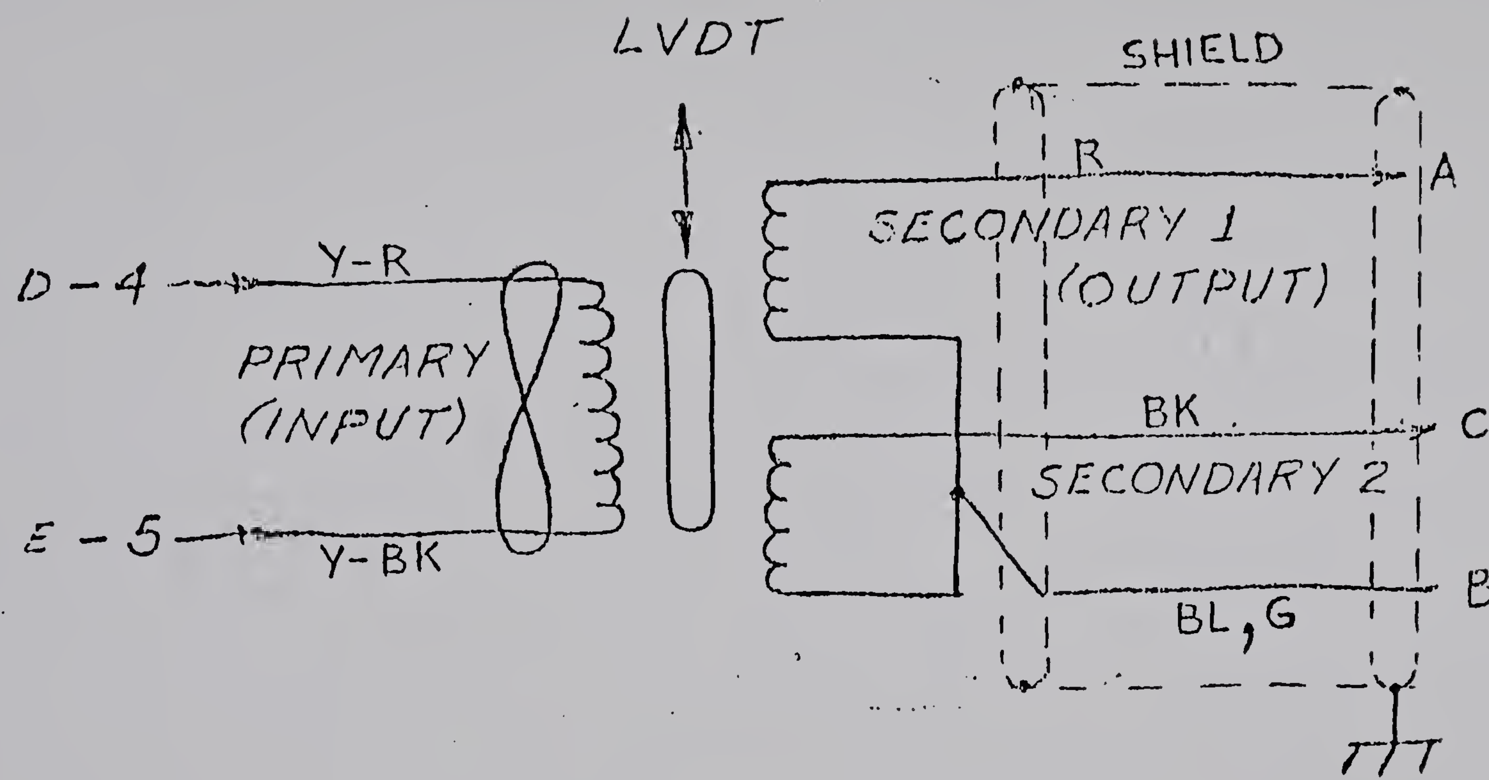
2.1.1 Range

Frontal and Lateral	250 lb
Vertical	1500 lb

2.1.2 Compliance

Frontal and Lateral	2.4×10^{-4} in/lb
Vertical	4×10^{-5} in/lb

2.1.3 Natural Frequency 7 Hz



PVC JACKET O/A

Wiring Diagram

APPENDIX C

VERTICAL JUMP BRIEFING SHEETS

November, 1981

IMMEDIATE POWER GAIN THROUGH A WARM-UP OF HIGH RESISTANCE EXERCISES

The aim of this study will be to explore the possibility of immediate power gain, as seen in the vertical jump, through a brief session of jumps with heavy weights.

The number of active motor units and their firing rate determine the force produced by a muscle. An electromyograph (EMG) can detect the electical impulses leading to motor unit activation. An integrated EMG can take into account the number of motor units recovered, their firing rate, and amplitude; therefore describing fully the electrical activity within muscles. A force plate could confirm an increase in force exerted, while a filmed jump test will reveal how this relates to performance.

Procedure:

1. The right quadricep (rectus femoris) and iliac crest (ground electrode) are prepared for electrode application. The two electrodes on the rectus femoris are placed on the mid portion of the muscle in a longitudinal plane about five centimeters apart from each other.
2. The subject stands behind the force plate with relaxed quadriceps.
3. The cameras are switched on.
4. The subject steps to the center of the force plate and immediately performs a maximal vertical jump.
5. The cameras are switched off.
6. A one minute sitting recovery is allowed between trials.
7. Steps 2 to 6 will be repeated with these variations:
    - I. Control Group "A" subjects will do seven more jumps without the weight bar on the shoulders.
    - II. Control Group "B" subjects will be given a seven minute recovery followed by a post-test jump.
    - III. Experimental Subjects will perform six more jumps with a 40 to 80 kg weight bar on the shoulders followed by a post-test without weights.

APPENDIX D

VERTICAL JUMP CONSENT FORM AND ASSIGNMENT CARDS

♀

Name wt. (Kg)
Sports Age

Trial	1	2	3
	B	Exp.	A
Time	____	____	____

I have been briefed on the procedures of this experiment and give my consent as a subject

____

APPENDIX E

SHOT-PUT BRIEFING SHEETS

<u>The Effect of using a Heavier Shot in warm-up on Standing Shot Put Performance</u>

This is the third and final portion of testing to be conducted for my study. In this experiment it is necessary that you come on three different occasions. You will act as a control subject on 2 occasions and as an experimental subject on the third.

Procedure:
].If you wish you may stretch before putting the shot but this must be kept consistent for the three days.

2. Pre test; take one maximal standing shot put with the regulation weight shot.

3. Control "A" subjects - six more maximal standing puts will be taken with the regulation weight shot. (one minute recovery between)

Control "B" subjects - simply take a seven minute recovery before doing the post test.

Experimental subjects - six more maximal standing puts will be taken with a heavier shot. (one minute recovery between puts)

4. Post test; take one maximal standing shot put with the regulation weight shot.

Thanks once again for being a subject.

APPENDIX F

SUPPLEMENTARY SHOT-PUT QUESTIONNAIRE

Effect of using a Heavier Shot ~~in~~ on Warm up on Shot Put Performance

A hypothesis has been developed that suggests that a warm-up with increased resistance may aid explosive power events. This simple experiment will test this hypothesis in an actual competitive situation.

Instructions for subjects:

1. Warm-up in your usual manner with the only variation being that all warm-up puts will be with a heavier shot; men use approx. 20 lb shot, women use either 12 or 16 lb shot.
2. Answer the following questions after the competition and return this sheet to me.

Name Sandi Ketterer Age 18

If female which shot did you use in warm-up? 12, 16 lb.
How many warm-up puts did you take? standing 4, with glide 2
What is your best shot put performance? 13.78, date Jan. 1982, comp. Golden Bear ~~[illegible]~~

What are your recent performances?

performance	date	comp.
13.46	Jan.'82	Age Class Champ
13.76	Feb 20/82	Alta. Seniors Champ
13.78	Jan '82	Golden Bear
—		

How many years have you been competing in shot put? 3 1/2

Have you used this type of warm-up before? Yes

Comment on factors, other than this warm-up, which probably affected your performance today? eg. no competition, injury, fatigue etc.

A groin pull was a bit of a hindrance; Didn't have much speed either— technical problems!

Further comments are welcome. Thank-you for your co-operation.

a heavier shot is a good way to warm up for me because it slows you down abit, thus you can feel your position better and when you get back to your normal shot, you have more spring.

13.42 13.39 13.76 13.39 13.45 13.76

A hypothesis has been developed that suggests that a warm-up with increased resistance may aid explosive power events. This simple experiment will test this hypothesis in an actual competitive situation.

Instructions for subjects:

1. Warm-up in your usual manner with the only variation being that all warm-up puts will be with a heavier shot; men use approx. 20 lb shot, women use either 12 or 16 lb shot.
2. Answer the following questions after the competition and return this sheet to me.

Name Lorie Thomas Age 18

If female which shot did you use in warm-up?. 12, 16 lb.
How many warm-up puts did you take? standing 6, with glide 3
What is your best shot put performance? 11.47, date ______, comp. ______

What are your recent performances?

Performance	date	comp.
11.47		Knights Columbus ~~Age Class~~
11.27		Golden Bear
11.17		Age Class
—		

How many years have you been competing in shot put? 1

Have you used this type of warm-up before? No

Comment on factors, other than this warm-up, which probably affected your performance today? eg. no competition, injury, fatigue etc.

No glide
Low angle of release
Didn't peak at all
} over all just an off day

Further comments are welcome. Thank-you for your co-operation.

Your thesis has possibility. I feel this would work, only I hit a really low day. Has been going well for a month, guess I had to have a bad meet somewhere.

/ / 9:50 10:21 / 9:86 10:21

A hypothesis has been developed that suggests that a warm-up with increased resistance may aid explosive power events. This simple experiment will test this hypothesis in an actual competitive situation.

Instructions for subjects:

1. Warm-up in your usual manner with the only variation being that all warm-up puts will be with a heavier shot; men use approx. 20 lb shot, women use either 12 or 16 lb shot.
2. Answer the following questions after the competition and return this sheet to me.

Name Chris Dallin Age 18

If female which shot did you use in warm-up? 12 , 16 lb.
How many warm-up puts did you take? standing____, with glide____
What is your best shot put performance? 12.05 , date Mar.8_ comp. W.Can. Jun

What are your recent performances?____,date____,comp.____

practice. 11.05 Dec

11.20 Dec.

How many years have you been competing in shot put? 3

Have you used this type of warm-up before? No

Comment on factors, other than this warm-up, which probably affected your performance today? eg. no competition, injury, fatigue etc.

- Have had a three week rest and felt strong
- No fatigue.
- Injury kept me from training.

Further comments are welcome. Thank-you for your co-operation.

- This warm up gives a kind of psychological advantage. The shot feels lighter when the correct weight is used.
- I might use this warm-up in the future.

11.81, 12.12

A hypothesis has been developed that suggests that a warm-up with increased resistance may aid explosive power events. This simple experiment will test this hypothesis in an actual competitive situation.

Instructions for subjects:

1. Warm-up in your usual manner with the only variation being that all warm-up puts will be with a heavier shot; men use approx. 20 lb shot, women use either 12 or 16 lb shot.
2. Answer the following questions after the competition and return this sheet to me.

Name Thom Denommé Age 19

If female which shot did you use in warm-up? 12 , 16 lb.
How many warm-up puts did you take? standing____, with glide____
What is your best shot put performance? 12.89 , date DEC/80, comp.____
What are your recent performances? 12.00 ,date JAN/82 ,comp.____
12.00 DEC/81

How many years have you been competing in shot put? 3

Have you used this type of warm-up before? No

Comment on factors, other than this warm-up, which probably affected your performance today? eg. no competition, injury, fatigue etc.

Knee injury, collarbone injury, fatigue, back

Further comments are welcome. Thank-you for your co-operation.

Weight not really a substantial difference.

11.46 11.91 10.88 11.49

A hypothesis has been developed that suggests that a warm-up with increased resistance may aid explosive power events. This simple experiment will test this hypothesis in an actual competitive situation.

Instructions for subjects:

1. Warm-up in your usual manner with the only variation being that all warm-up puts will be with a heavier shot; men use approx. 20 lb shot, women use either 12 or 16 lb shot.
2. Answer the following questions after the competition and return this sheet to me.

Name KEVIN McKENDRY Age 23

If female which shot did you use in warm-up?. 12 , 16 lb.
How many warm-up puts did you take? standing 5 , with glide 1
What is your best shot put performance? / , date FEB/21, comp. ALTA SENIOR
What are your recent performances? 12.57 ,date DEC 15, comp. WARM - UP

12.57	DEC 15	WARM - UP
13.02	JAN/5	TAE MEET
12.95	FEB/6	GOLDEN BEAR
13.03	FEB/21	ALTA SENIORS

How many years have you been competing in shot put? 10

Have you used this type of warm-up before? NO

Comment on factors, other than this warm-up, which probably affected your performance today? eg. no competition, injury, fatigue etc.

–

Further comments are welcome. Thank-you for your co-operation.

Good for warm-ups, easy to handle, improves ability to finish throw.

12.00 12.27 12.86 12.90 13.03

Effect of using a Heavier Shot on Warm up on Shot Put Performance

A hypothesis has been developed that suggests that a warm-up with increased resistance may aid explosive power events. This simple experiment will test this hypothesis in an actual competitive situation.

Instructions for subjects:

1. Warm-up in your usual manner with the only variation being that all warm-up puts will be with a heavier shot; men use approx. 20 lb shot, women use either 12 or 16 lb shot.
2. Answer the following questions after the competition and return this sheet to me.

Name Glenn Runcie Age 31

If female which shot did you use in warm-up? 12 , 16 lb.
How many warm-up puts did you take? standing 4 , with glide 6
What is your best shot put performance? 15.12 , date ______, comp. ______

What are your recent performances? 15.12 ,date ______ ,comp. The Meet VI
14.76 goldenbear
14.67 AlbertaClt.

How many years have you been competing in shot put? 3

Have you used this type of warm-up before? no

Comment on factors, other than this warm-up, which probably affected your performance today? eg. no competition, injury, fatigue etc.

I am in the middle of a heavy weight training phase and I am a bit fatiqued, Bronchitis, No technique work ∴ erratic

Further comments are welcome. Thank-you for your co-operation.

Discus training + warm-up with heavier

14.25 14.67 14.35